GENERAL MOTORS

Engineering JOURNAL

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ENGINEERED STEERING

On Automotive Engineering

PROGRESS in automotive engineering benefits many other product areas, some of which are entirely out of the transportation field. This is a valuable by-product of the services rendered by automotive engineers. These engineers also draw ideas for automotive advancement from many other technological fields. Thus, automotive engineers both give to and receive from engineers in other fields.

The 1955 models are well-known now to almost every individual and the advancements in them are generally accepted as examples of engineering progress, as well they may be. A professor from Illinois writes that the automobile is perhaps the one product which brings everyone into close touch with the engineering world. In my opinion, this fine tribute to men concerned with improving transportation is not overenthusiastic. A consideration of all of the separate technological fields represented in the automobile will demonstrate the universality of the engineering in it.

Take from any 1955 automobile all of those parts made of *rubber and glass*, and consider the advances which have come about in these fields because of the needs of the automobile. Their applications in non-transportation products contribute greatly to our high standard of living.

Now remove all the *hardware and textile products*, the development of which has benefited many other materials and products of our economy.

Next, take out all *instruments and electrical products*. Here, progress for the automobile has become interwoven with a great variety of other indispensable equipment.

Remove the springs, bearings, and *machine shop products* and here also you immediately observe that the work of the automotive engineer has been profitable to other engineers.

When the steering wheel and column, the entire engine block, power train, and other *forge and foundry products* come out, the application of automotive engineering practices in other areas becomes even more clear.

When all these have been removed the only items remaining are the body, frame, bumpers, and a few other *stamped parts*. Automotive advances in stamped parts flow over into many other industries.

When all automotive components have been designed and fabricated, an immense field of automotive engineering contribution remains. That is the *assembly operation*, in which the industry has established patterns for many others.

The applications of automotive engineering principles to non-automotive products would be too numerous to list here for any one of the seven fields. Perhaps the best historical example of how automotive engineering knowledge adapts itself to other projects is the contribution of the industry to the success of the World War II all-out production effort.

Automotive vehicles are foremost to the automotive engineer, but his calling has many plus factors affecting our entire economy. Yet, excellence of automotive engineering is almost taken for granted by the public. Being taken for granted is one of the highest tributes which can come to any servant of mankind, and places a challenge before the man who becomes an automotive engineer.

Charles A. Chayne,
Vice President in Charge of Engineering Staff

THE COVER

Another portrayal of transportation developments is this issue's cover design—Engineered Steering—by artist Ernest W. Scanes. A recirculating ball steering gear represents the manual-control mechanisms which have been used successfully on millions of automobiles and trucks. The test tube of oil symbolizes the application of hydraulic principles to further improve steering control. The levers and fulcrums symbolize the differences in torque resulting from conventional and power assisted steering. Hydraulic steering was developed and introduced first on heavy, specialized vehicles and later on passenger cars and trucks. Public acceptance of power steering has proved the value of this latest application of engineering fundamentals to new devices for simplifying the driver's function of steering.

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The GENERAL MOTORS ENGINEERING JOURNAL is published every other month by the Educational Relations Section of the Department of Public Relations, General Motors Corporation, and is intended primarily as a medium for presenting to the field of engineering education the results of General Motors research and engineering developments both in the product and production fields.

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A Summary of Major Developments in the Steering Mechanisms of American Automobiles

By C. W. LINCOLN
Saginaw Steering Gear Division

A chief engineer views the technical advances in his field

When the internal combustion engine began to substitute for the horse as a carriage propulsion means, automotive experimenters of the late 19th century looked to the carriage industry for ideas. Only two little-used but valuable principles drawn from the carriage industry remain in today's automotive vehicles. The Lankensperger-Ackermann non-turning front axle with individually turnable wheels gave the automobile a four-square support. The French development, sometimes called the Jeantaud linkage, gave the cross tie rod, which connected the levers or *plain arms* by which the left and right wheels could be turned simultaneously. With these two steering principles, the pioneer contributors to American mass-produced automobiles, including Saginaw Steering Gear Division founded in 1906, devoted engineering efforts to providing mechanical advantage to the driver. Cars and trucks of the late 1920's were made heavier and more efficient gearing was needed, and within the next decade all three major steering gear manufacturers were producing antifriction gears. In the next decade, from 1930 to 1940, Saginaw developed the circulating-ball-type gear. World War II delayed development of lighter gears for cars but furthered the development of power steering. In 1951 and 1952, engineering attempts to keep steering effort down resulted in the offering of hydraulic power steering. General Motors offered an integral power gear developed by Saginaw Steering Gear Division. In the last few years, steering gear manufacturers have been experimenting with *booster-* or linkage-type hydraulic gears.

THE gasoline automobile is a little over a half-century old. During the last two decades of the previous century, each of a few pioneers produced an individual vehicle powered by an internal combustion engine and intended to transport passengers over roads. These forerunners of production automobiles were light-weight and low-powered vehicles, most of which were attempts to apply self-propulsion to the existing horse-drawn carriage.

As could be expected, some of these early automobiles retained the rigid front axle of the carriage. To turn a corner, the entire axle—front wheels and all—pivoted about a vertical axis at the midpoint of the axle. The axle position was controlled, at least to some extent, by means of a king-post extending upward through the floor boards, and a tiller of some description fastened to the king-post.

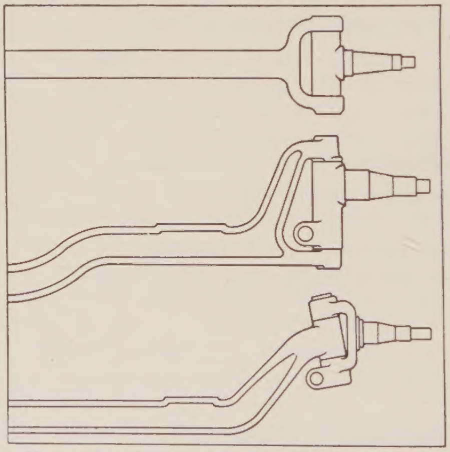


Fig. 1—Steering knuckles for motor vehicles are derivatives of the Lankensperger-Ackermann non-turning front axle in which each wheel has its own pivot point. The complications which would have resulted by using a turnable front axle would have included a requirement for smaller wheels and larger clearance areas, reduced automotive speeds, adverse vehicle suspension characteristics, and a host of other problems which automotive engineers do not like even to contemplate.

Making the Front Axle Stationary

Many years earlier, however, a German carriage maker by the name of Lankensperger had invented a different type of front axle (Fig. 1). This axle did not swing as the front wheels turned. It was, rather, restricted to a transverse position in the vehicle. At each end of the axle, about a substantially vertical axis, a part was pivoted to it which included a horizontal sub-axle for the wheel. This part is the one that is now called the *steering knuckle*. Lankensperger's non-turning front axle, with separate vertical axes at its two ends, was patented in England by his agent, Rudolph Ackermann. An axle of this type is still known in English-speaking countries as an *Ackermann axle*.

Although the Ackermann axle was invented for carriages, it failed to achieve material recognition until the automobile came along and needed it. A number of early experimenters adopted the axle because it did several things for them. The contact points of the front wheels with the ground did not move materially with respect to the frame of the vehicle, whether driving straight ahead or turning a corner. Thus, the automobile was assured of four-square support at each of its corners—turn or no turn. Such objectionable features as reducing the size of the front wheels and arching the frame of the vehicle to clear them were avoided. The wheels and tires could all be identical and side members of the frame could be straight and strong. These advantages quickly doomed the swiveling front axle. Since the beginning of American automobile *manufacturing* at the turn of the century, each front wheel has pivoted on its own axis, close to the plane of the wheel.

The Tie Rod Is Born

Of course, it was soon discovered that, to make a turn without scuffing the tires, the front wheel on the inside had to move through a greater angle than the one on the outside. The problems attendant with devising a front-end linkage to accomplish this properly have not yet been solved completely.

The theoretical requirement is that, to accomplish a turn without scuffing of any of the wheels, the axes of all four wheels must intersect the same vertical line, which becomes the axis about which

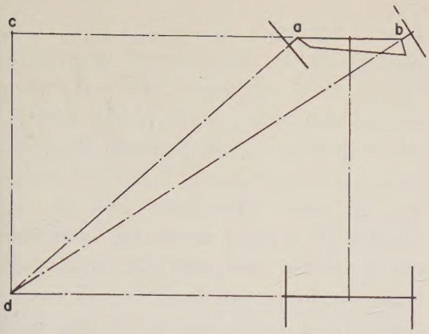


Fig. 2—It is a theoretical impossibility to turn a vehicle without scuffing tires, although today's compromise solutions have made the problem as negligible as possible. Here the vehicle is in an ideal turn about point **d**, which may be assumed as a straight line emerging from the paper. Assuming proper vertical inclination of the wheels, the turn is perfect because the lines **ad**, **bd**, and **cd** all intersect the line (point) **d** and together the three lines represent an extension of the axis about which each wheel rotates on its bearings.

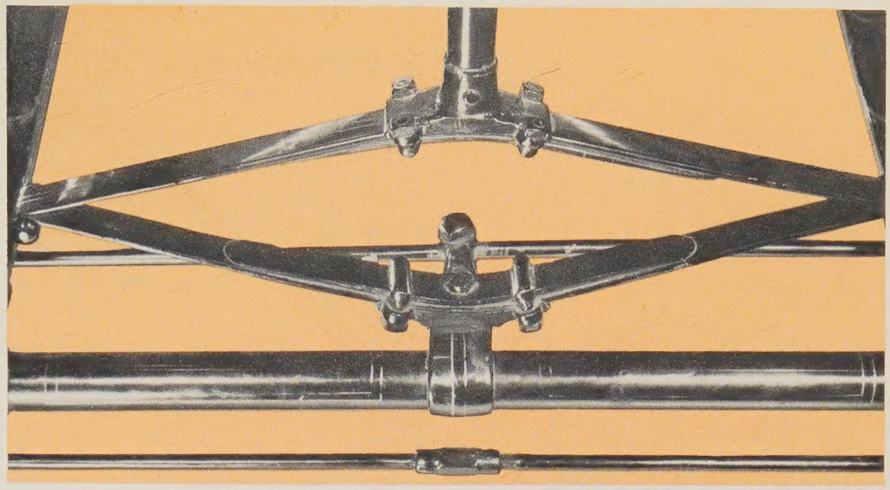


Fig. 3—The 1901 Oldsmobile used an adaptation of the Lankensperger-Ackermann independent wheel-turning feature and the plain links were connected by a cross tie rod which controlled at its central pin joint by means of the vertical tiller shaft.

the vehicle turns (Fig. 2). Since in all conventional automobiles the axis of the rear wheels is confined to a transverse plane, this means that, in the plan view of the vehicle, the axes of the two front wheels must always intersect the axis of the rear wheels at the same point. While it is not possible to devise a simple pin-jointed linkage between the two steering knuckles which would accomplish this result to perfection, there are approximations which satisfy all practical requirements.

The basic approximation is one in which arms attached to the steering knuckles extend rearward and toward the center plane of the vehicle (pointing in the general direction of the present-day differential), and are connected together at their rear ends by a simple tie rod. The arms are usually known as the *plain arms*, and the rod as the *cross tie rod*. Such a linkage is sometimes known as a *Jeantaud linkage*, as it was actually used by a French carriage builder of that name as early as 1878. All practical front-end linkages are either the Jeantaud linkage or modifications of it.

The Pin Joint Needed a Controlled Force

Given the Ackermann axle and the Jeantaud linkage, the only remaining steering requirement was that of a device of some kind to transmit the steering effort from the hands of the driver to the linkage. Since early automobiles were light in weight and slow in speed with solid or high-pressure tires of small cross section, it didn't take much force to change the direction of the front wheels, and the transmitting device was often simplicity itself. The Merry Oldsmobile, for example, started out by putting a pin joint in the middle of the cross tie rod, and connecting in at the joint the outer end of a short arm attached to the bottom of a vertical tiller shaft (Fig. 3).

This steering mechanism was an example of a very simple modification of the Jeantaud linkage made, in this case, to accommodate the device transmitting the steering effort from the driver's hands. Likewise, it was an example of a transmitting device simple in the extreme. This car may be considered as first in the line of automobiles to be manufactured in appreciable quantities, as 400 of them were produced in the year 1901.

The automobile matured through the years under the nurture of engineers. During the first decade of the present century, it began to be developed from the horseless carriage into a relatively self-sufficient vehicle of the general functional lines which are retained today. Engines were taken from under the seats to positions forward of the dash and under a hood, with the line of the crankshaft fore-and-aft, rather than transverse. Steam and electric cars withdrew from the field, leaving gasoline supreme. The transition from chain drives to propeller shafts began. Power, weight, and size consistently increased, and the pressure in pneumatic tires began to go down as their cross-sectional dimensions increased.

The upshot of all this was that, to hold steering efforts within reason, reducing gears soon had to be inserted between the hands of the driver and the front wheels of the vehicle. As this move was made, the automobile steering gear, as it is thought of today, was born.

Most of the early steering gears included a cast gear box mounted on the frame of the vehicle, and housing a driving and a driven gear (Fig. 4). The gears themselves were, in many cases, the well-known worm and worm wheel. The worm shaft, known then and now as the *steering shaft*, extended through the upper end of the gear box and inclined rearward and upward toward the driver. At its upper end the shaft was adapted to receive a handwheel which became known as the *steering wheel*.

The steering shaft was surrounded by a thin-walled tubular jacket fixed firmly to the upper end of the gear box and carrying at its upper end a bearing for the upper end of the shaft. The jacket and the shaft within it continue to the present, and are often designated collectively as the *steering column*. The worm-wheel shaft extended through the side of the gear box and was fitted at its outer end with an arm hanging substantially downward. The worm-wheel shaft (or its equivalent in variant steering gears) has been known as the *cross shaft* or *pitman shaft* of the gear, and the arm has been known as the *steering arm*, *drop arm*, or *pitman arm*. All steering gears of the day were largely self-locking, or irreversible, an advantage in driving over the rutted roads then available.

The adoption of the gear box, with its downward-hanging steering arm, brought one complication to the front-end linkage, and relieved it of one other. Since the motion at the lower end of the steering arm was essentially fore-and-aft,

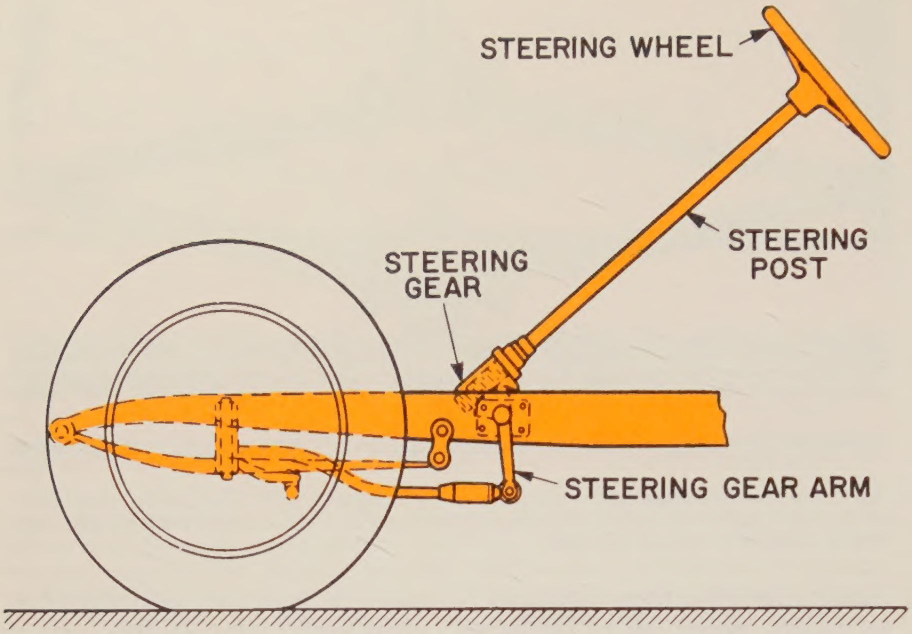


Fig. 4—The old worm and worm-wheel principle found a new application in early steering systems. This combination in a gear box mounted on the chassis multiplied the torque resulting from the driver's hand on the steering wheel. The driven gear moved the steering gear arm fore-and-aft. Because the driver sat on the left side of the vehicle, engineers had to add an arm extending toward the vehicle's center onto the left wheel's steering knuckle.

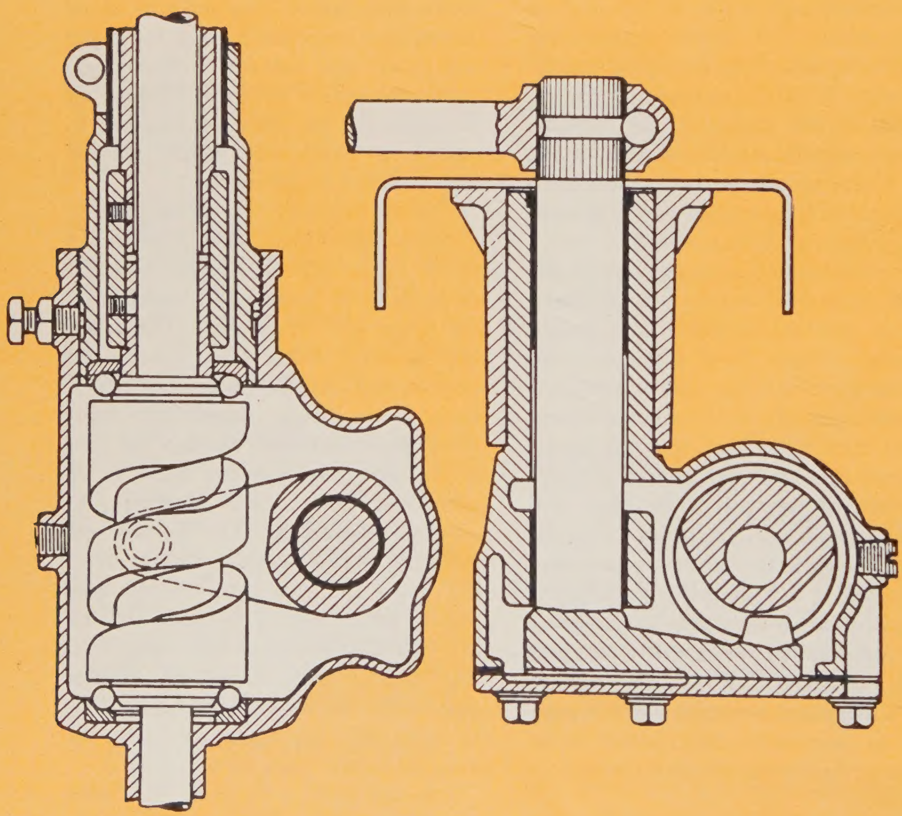


Fig. 5—In the cam-and-lever steering gear, introduced in 1923, the steering effort was applied through a coarse-pitch worm groove to a pin on the outer end of a lever (right). The lever applied torque to a rod which, in turn, transmitted steering effort to the steering gear arm.

it was necessary to equip the steering knuckle on the steering gear side of the vehicle with an extra arm extending toward the center plane of the vehicle, and to provide a link between the outer end of this arm and the lower end of the steering arm. The extra arm of the knuckle was known as the *third arm* (the wheel spindle itself and the plain arm being the first two), and the link to the steering arm was known as the *drag link*. Ball joints were adopted at the ends of the drag link, as motion occurred in more than one plane at each end. With the steering effort transmitted to one front wheel by means of the drag link, the jointed cross tie rod was no longer required and the connection between the front wheels reverted to the basic Jeantaud linkage. The drag link and the simple tie rod were to continue for many years on most automobiles and continue to the present on many trucks.

Saginaw Steering Gear Division Is Founded

During the first years of this century, the details of automobile construction were beginning to attract the attention of independent inventors. As a result, businesses were springing up which were destined to become manufacturers of particular automotive *components*.

In 1906, for example, three men of Saginaw, Michigan, incorporated a company for the manufacture of automobile parts. Within a year, two similar companies were formed and began operations elsewhere. All three of them were engaged in the manufacture of automobile steering gears by 1908. All of them have continued such manufacture to the present.

The history of Saginaw steering gears, and all other American steering gears from 1908 to 1923, is largely a history of developments which consisted mainly of experimentation with the type of gearing to be used within the gear box. Since none of them continued on into the passenger car of today, they may be passed over somewhat briefly.

The first Saginaw gear was one in which a straight worm or screw was provided with crossed right- and left-hand threads. The worm meshed with half nuts on either side, one nut provided with right-hand threads and one with left-hand. The lower ends of the nuts bore against opposed ends of a rocker arm, integral with the external steering

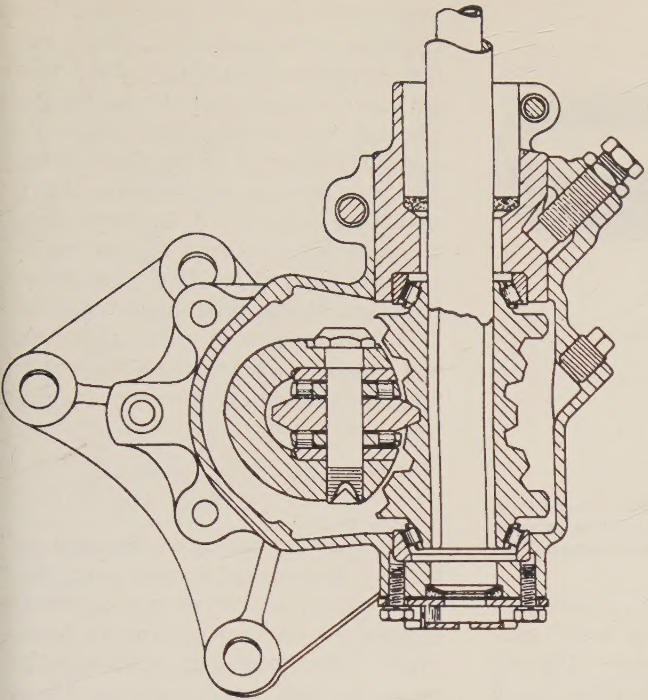


Fig. 6—The hourglass-type worm gear combined with a roller tooth which was attached to the pitman shaft which, in turn, was connected to a steering arm. This gear's design reduced friction to levels below that in former types and made the steering gear box both smaller and more efficient.

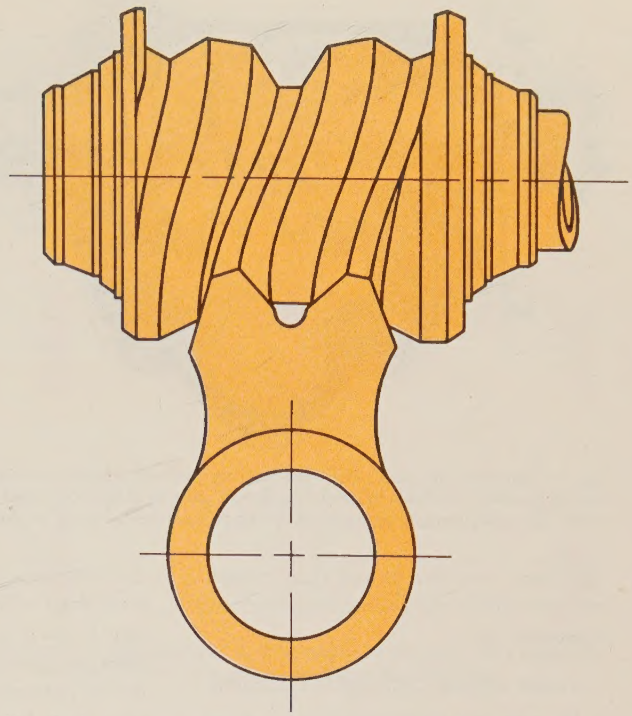


Fig. 7—Saginaw's worm-and-sector gear used an hourglass worm. The helix angle of the worm was considerably greater than in worm and worm-wheel gears with a consequent increase in efficiency.

arm. Thus, the gear, known for many years as the *Jacox*, was basically of the screw-and-nut type. With occasional improvements in construction, it was manufactured by Saginaw for nearly twenty years. During this period the Saginaw Company became the property of the Buick Motor Car Company of Flint, Michigan, and later was made the Saginaw Steering Gear Division of General Motors Corporation.

During this 15-year period, many mechanisms were designed and tested by each of the three traditional producers. Perhaps the most successful were basically of the screw-and-nut type, with various devices for conversion of the reciprocating motion of the nut to the oscillating motion of the steering arm. Manufacture of a worm-and-sector gear, modern for the day, was begun as early as 1909 and gears of this basic type continued in use on passenger cars well into the 1930's. Some are still used on a small number of farm and industrial tractors.

Saginaw Steering Gear started out with a gear basically of the screw-and-nut type. It may be that this was an attempt to break away from the well-known worm and worm wheel in the hope of offering something better. It is worth notice that during this 15-year period there was a gradual trend toward higher ratios in steering gears. This was the result of an attempt to keep steering effort down as the weights of cars constantly increased, tires became still larger and softer, and really heavy trucks came into the automotive field. Roads were becoming better too, and as speeds increased, the advantages of handling a vehicle with a measure of reversibility in the steering mechanism were becoming apparent. The completely irreversible gear was no longer the ideal.

The Cam-and-Lever Gear Is Introduced

The cam-and-lever steering gear was the first one on the scene which still survives in some American passenger cars (Fig. 5). It embodied a worm or screw with a coarse-pitch thread groove, a lever on the inner end of the driven shaft or cross shaft which rotated in a plane parallel to the axis of the screw, and a pin in the outer end of the lever which engaged the thread groove of the worm. Machines specially designed for cutting the thread groove of the worm made it possible to secure smooth action in spite of the arcuate path described by the axis of the pin and even to vary the gear ratio, within limits, for varying positions of the cross shaft. The gear was unusually compact and a degree of reversibility could be attained. This gear was manufactured, substantially without change, for the next five years.

Meanwhile, Saginaw continued with the Jacox gear. Another gear was added, however, in 1926. In that year a typical worm and worm-wheel gear was brought out, and first sold to Cadillac Motor Car Division.

But cars and trucks were still growing heavier, and the limit to reducing steering effort by increasing gear ratios was approaching. It was not possible to turn the steering wheel through too many turns in handling the vehicle, and the size of gearing had to be held within reason. What was needed was not larger gearing, but more efficient gearing.

The Roller-Tooth Gear Is Introduced

The roller-tooth steering gear was the first to substitute rolling contact for sliding contact between major components of the mechanism (Fig. 6). It combined a worm of the hourglass type with an offset roller mounted in the cross shaft, or pitman shaft, and had the periphery of the roller formed into the contour of a worm-gear tooth. Samples of this gear were actually built as early as 1921, but first marketed in 1926. The

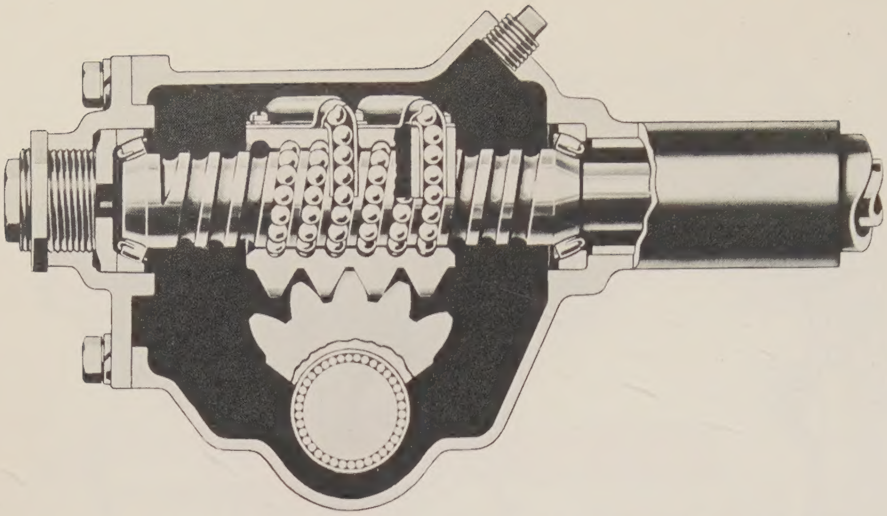


Fig. 8—Saginaw's circulating-ball-type steering gear was actually a reversion to the screw-and-nut type, but with antifriction balls between the thread grooves of the screw and the nut. The nut was provided with rack teeth engaging sector teeth on the pitman shaft. Heavy production of this gear began in 1941.

roller-gear was the second type of steering gear which still survives in American passenger cars.

Modern Manual Steering Is Developed

Modern manual steering was developed during the eight-year period from 1928 to 1936. (Power steering for passenger cars was still far in the future.)

Saginaw Steering Gear, which had assumed on New Year's Day of 1928 its present designation as Saginaw Steering Gear Division, General Motors Corporation, stayed briefly with the Jacox and the worm and worm-wheel gears, but in 1929 brought out (for the General Motors 5-ton truck) its first worm-and-sector gear (Fig. 7). This gear used an hourglass worm. The helix angle of the worm was considerably greater than in the old worm and worm-wheel gears, with a consequent increase in efficiency.

By 1930, Saginaw Steering Gear was making the worm-and-sector gear in various sizes for all General Motors cars except the Buicks and the Chevrolets. For Buick Motor Division, Saginaw Steering Gear made its first gear of the roller-tooth type. At the same time the Jacox, the last of the screw-and-nut gears, was dropped from production. Chevrolet switched from its own worm and worm-wheel gear to the Saginaw worm-and-sector type in 1931. This move marked the demise of the old worm and worm-wheel gears, except in a few trucks and some farm tractors. In 1933, Saginaw introduced the first ball bearing roller-tooth in a gear.

In 1934, one manufacturer increased the angular travel of the steering arm in the cam-and-lever gear by providing the cross shaft with a forked or "twin" lever gear in place of the single lever. The new lever was provided with two pins, one of which entered the worm thread as the other was leaving it. In 1936, a twin-lever gear was provided with roller bearing pins, as had been done for the single lever.

Thus, by 1936, the three major steering gear manufacturers were producing antifriction steering gears, although simpler gears were still available and in limited use. This condition still prevails, although the proportion of antifriction gears in use has steadily increased.

The production of passenger cars, and with it the development and production of most steering gears, was soon to be halted by World War II—but not until Saginaw Steering Gear had made another important contribution.

This Division began experimenting with a novel gear which was actually a reversion to the screw-and-nut type, but with antifriction balls between the thread grooves of the screw and the nut (Fig. 8). The nut was provided with rack teeth engaging sector teeth on the pitman shaft. This gear could be designated as of the circulating-ball type. A few were produced for some General Motors trucks and they were on the 1940 12-cylinder Cadillacs. Heavy production began in 1941, with the gear in use on all Buicks and Cadillacs, Chevrolet trucks, and a large proportion of General Motors trucks and coaches.

Passenger Car Power Steering Is Developed

All of the steering gears discussed so far have been *manual* steering gears. By this is meant that no power is provided to assist the driver in turning his front wheels. Some specialized vehicles, such as certain road construction machines and a few very large trucks, had already become so difficult to steer that power assisting devices had been provided on them; but power steering for passenger cars was still in the future.

World War II, while it delayed development in lighter gears for cars, was to further the development of power steering in general, and to bring the day nearer when such steering would be applied to great numbers of automotive vehicles.

Previously, most power steering for heavy vehicles had been of the hydraulic *booster type*. In this type, oil is placed under pressure by a pump belted to the engine and directed through a control valve in the steering linkage to a hydraulic cylinder. The cylinder's power

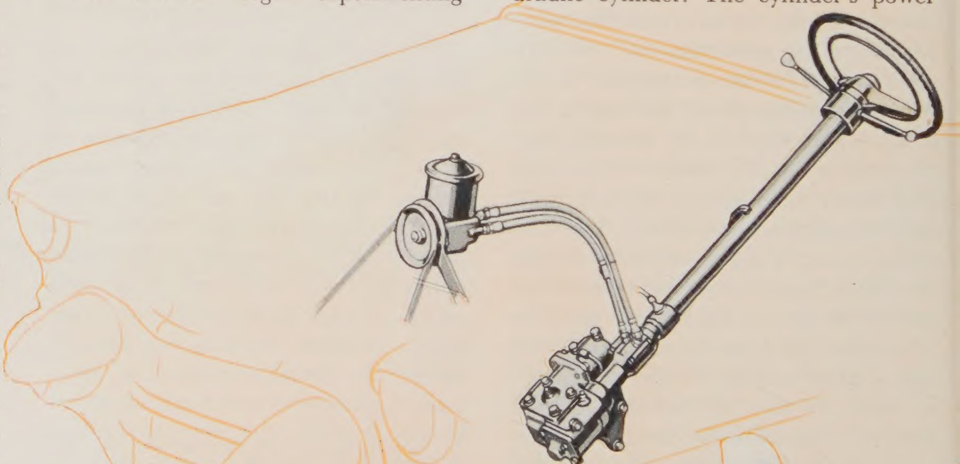


Fig. 9—The power steering gear developed by Saginaw employs a hydraulic pump driven by the engine of the car, control valves which are automatically operated by motion of the steering wheel, and power cylinders which transmit a piston motion directly to the cross shaft of the steering gears.

was applied to the linkage. In such applications, the manual steering gear was left substantially untouched. In 1942, however, Saginaw began furnishing *integral* hydraulic steering gears for military vehicles. In this gear the control valve and the hydraulic cylinder were bolted directly to the gear housing, the whole forming one compact package. All steering effort was applied to the steering linkage through the cross shaft of the gear.

When passenger car production was resumed following the War, it was with the same types of manual gears as before the War and there were no noteworthy developments until 1951. In 1950, Saginaw was furnishing circulating-ball gears for Cadillacs, Buicks, and Oldsmobiles, as well as most General Motors trucks and coaches, all Chevrolet trucks, and certain other vehicles. It was furnishing double roller-tooth gears (with ball-bearing rollers) for Chevrolet passenger cars and Pontiacs until the introduction of the 1955 models. It also continued with the old worm-and-sector gear for certain lesser vehicles.

Passenger Car Power Steering Is Marketed

In 1951 and 1952 the continuous research and development program to reduce steering effort and to increase safety brought the introduction of hydraulic power steering for passenger cars. General Motors offered a power gear developed and manufactured by Saginaw Steering Gear in Cadillacs, Buicks, and Oldsmobiles. This system employed a hydraulic pump driven by the engine of the car, control valves which were automatically operated by the motion of the steering wheel, and power cylinders which transmitted a piston motion directly to the cross shaft of the steering gears. Thus, it was an integral-type gear (Fig. 9).

The acceptance of power steering ranked well with the public reception of earlier major engineering developments and the great public interest in power steering attracted the attention of manufacturers not hitherto important in the building of steering apparatus. As Saginaw Steering Gear continued with integral gears for passenger cars, other firms began making experimental models of power steering apparatus of the linkage-booster type in the belief that the latter would cost less than the integral gears.

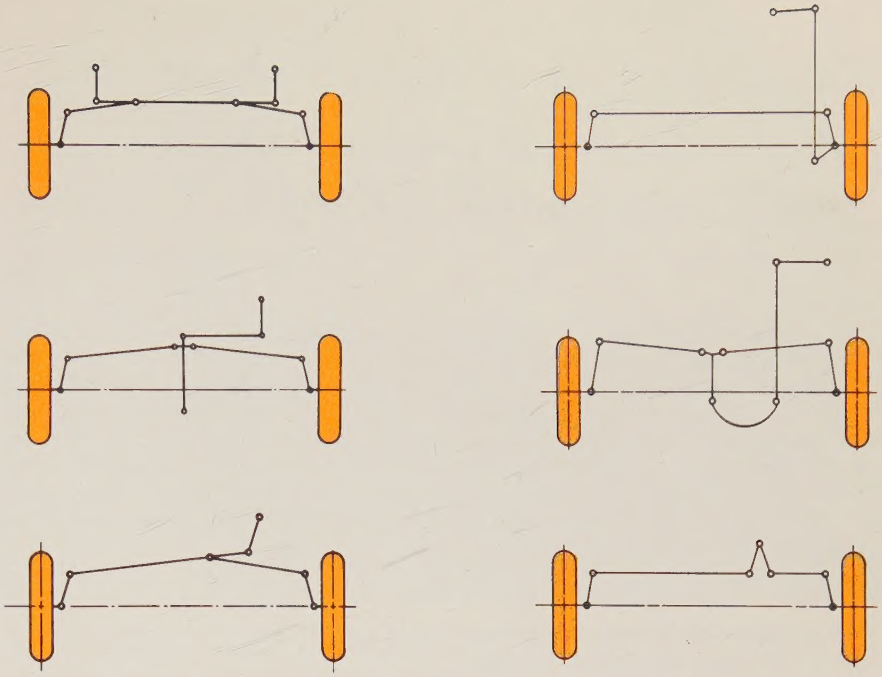


Fig. 10—These typical steering linkages are well-known to steering engineers but none has a uniformly acceptable name. The engineering principles involved are self-evident from the sketches.

Meanwhile, the three major steering gear manufacturers, including Saginaw Steering Gear, were also experimenting with linkage boosters. All General Motors cars, except the Chevrolet which began using a booster unit in 1955 and two models of another major manufacturer, are presently being offered with integral power steering gears, and nearly all other cars are offered with linkage boosters of various makes.

New Steering Linkages Are Developed

While the most important developments in automobile steering since the introduction of reduction gearing have been in the steering gears themselves, it is appropriate to take brief cognizance of certain changes that have been made in front-end linkages (Fig. 10).

While the simple combination of fore-and-aft drag link and plain cross tie rod is still used on many trucks, this has given way on most present-day passenger cars to other and somewhat more complicated types. Chief among these are the center-lever and parallelogram types. In the center-lever type of linkage, a fore-and-aft link transmits motion through separate tie rods to the two steering knuckles. In the parallelogram type, the pitman arm has a counterpart idler arm on the opposite side of the frame, and the outer ends of the two arms are connected by a cross rod. Separate tie rods transmit the motion from this cross rod to the two steering knuckles.

In the main, the changes in linkages have been brought about in order to avoid excessive changes in camber and direction of the front wheels during the action of the springs of various types of front suspensions and, in some cases, changes have been dictated by clearance considerations.

Summary

In the early days of automobile manufacturing, cars were of diverse sizes and weights. For the smaller cars, the early, simple gears sufficed. None of the early gears could be considered antifriction gears but antifriction gears of one type or another soon took their places on many makes of cars and trucks. By 1936 all of the major steering gear manufacturers were producing antifriction gears, although simpler gears were and are still available and in limited use. Saginaw developed the circulating-ball gear and it was put in heavy production in 1941. In 1942 Saginaw began furnishing *integral* hydraulic steering gears for military vehicles. Such units were first offered by General Motors on some of its cars in 1952. Meanwhile, steering gear manufacturers experimented with *booster*-type hydraulic gears. The first General Motors car to be offered with a booster-type hydraulic gear developed by Saginaw Steering Gear was Chevrolet in 1955 models.

Fabrication of a Welded Steel Crankcase for a Light-Weight Two-Cycle Diesel Engine

By ALBERT C. DRECHSLER

Cleveland Diesel Engine Division

A special engineering design required a special manufacturing process

The design specifications for a high-speed, two-cycle Diesel engine, recently developed by Cleveland Diesel Engine Division engineers, stated that all component parts be of the lightest weight and greatest strength possible. To meet the design requirements, the engine crankcase—which represented the largest and heaviest engine component—was to be constructed of a welded assembly of steel forgings and steel plates. In order that the welding operations performed be as automatic as possible, the manufacturing process engineer had to devise specialized welding fixtures and techniques which would result in the most efficient fabrication of 67 individual steel forgings and steel plates into a completed crankcase assembly.

The exacting and severe requirements of specialized application for high-speed Diesel engines create many problems which have to be solved by manufacturing process engineers if the demands made by the designer for least weight and greatest strength of engine parts are to be obtained. Such problems, involving weight and strength, were encountered by Cleveland Diesel Engine Division engineers in connection with the manufacture of a newly developed vertical, radial, 16-cylinder, two-cycle, high-speed Diesel engine (Fig. 1).

A major point of concern was the engine crankcase, which represented the largest and heaviest engine component. The specific type of service which the high-speed Diesel engine would perform required that the materials comprising the crankcase be able to withstand extremely high stresses and pressures.

Successively, during the last 20 years, the cast iron and then the cast steel crankcase had to be discarded for high powered Diesel engines because these materials could not withstand the millions of cycles of severe stress reversals for the particular type of service to which the engines were subjected. In order to satisfy the material demands for light weight, high strength, and resistance to shock, the crankcase was designed to be constructed of a welded assembly of steel forgings and steel plates, having the appearance of a well designed casting but possessing the physical properties of steel.

Once the overall crankcase design had been established, there remained the problem of setting up the production sequence of operations necessary to fabricate the welded crankcase assembly. This necessitated the development of specialized tools of production in the form of special welding machines, fixtures, and other equipment, as well as the initiation of new manufacturing procedures.

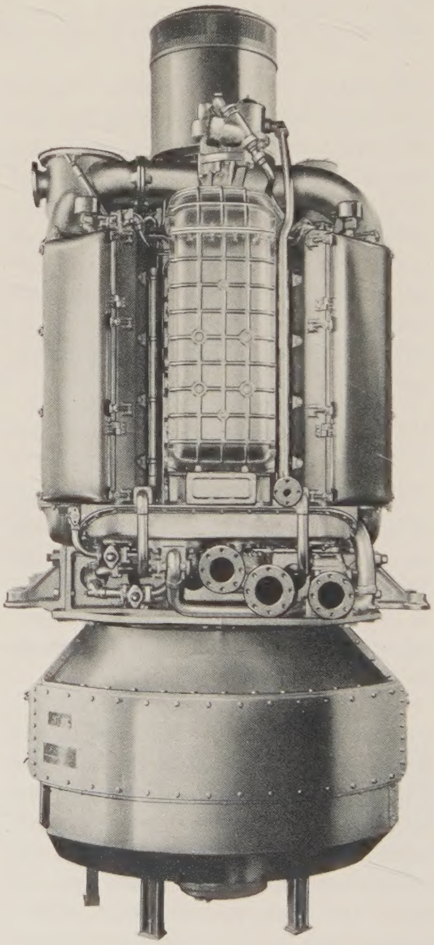


Fig. 1—To meet the design specifications for least weight and greatest strength of engine parts, the crankcase of the vertical, radial, 16-cylinder, two-cycle, high-speed Diesel engine was constructed of a welded assembly of steel forgings and steel plates.

Production Considerations

The production design of the crankcase called for the fabrication of 56 individual S.A.E. 4017 steel forgings and 11 flame-cut S.A.E. 1020 steel pieces into the completed crankcase assembly (Fig. 2).

This assembly, made up of an inner deck sub-assembly, stress members, outer deck sub-assembly, and stack-up sub-assembly, is 39½ in. high, measures 38 in. across diametrically opposite cylinder decks, has a 13½-in. diameter bore for main-bearing carriers, and has 16 cylinder-liner bores that measure 7⁹⁄₁₆-in. diameter in the outer decks and 6⅝-in. diameter in the inner decks. The total machined weight of the crankcase is 1,527 lb and 100 per cent X-ray inspection of all load carrying welds is mandatory.

The first crankcases produced were fabricated entirely by hand welding techniques using a power-driven welding positioner of standard design (Fig. 3). The hand welding method of fabrication was used as a basis for developing welding procedures and fixtures necessary for required production fabrication. The experience gained from the hand welding techniques aided materially in pointing out where possible difficulty in fabricating the sub-assemblies would exist.

During the hand welding operation, considerable difficulty was experienced in obtaining clean, slag-free joints having 100 per cent penetration and no cracks. There also was a question as to the

Fig. 2—The completely welded and machined crankcase assembly consists of 56 individual steel forgings and 11 flame-cut steel plates.

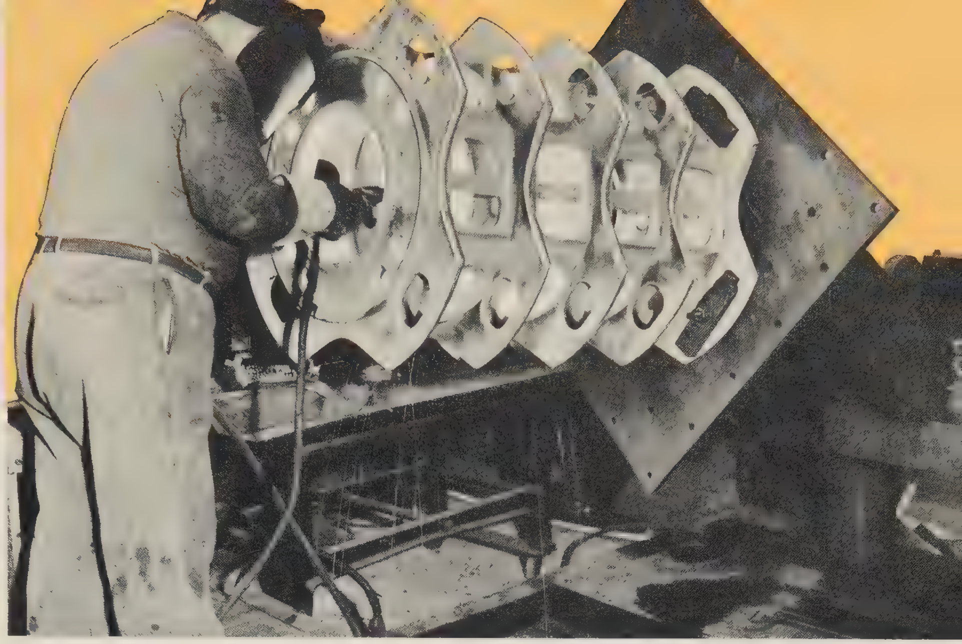


Fig. 3—The first crankcases produced were fabricated entirely by hand welding techniques using a power-driven welding positioner. The hand welding method of fabrication served as a basis for the development of welding procedures and fixtures necessary for the production run.

shrinkage allowance, which in welding processes is always problematical until proven. It was shown that the stack-up design of the crankcase multiplied shrinkage allowance errors eight times.

The defective weld metal resulting from the hand welding operations had to be removed by hand. This was accomplished by using high-speed, air-driven grinders with carbide burring cutters. This proved to be a very time-consuming and costly operation—although there was no other way to remove the defective weld metal. Since the best way to reduce the cost was to reduce the necessity of having to remove defective weld metal, this consideration led to the use of the submerged-arc welding process in conjunction with specially designed welding fixtures and positioners for all production runs.

The *submerged-arc welding process* is a method of welding electrically beneath a layer of granular and molten mineral material. The granular material is laid down directly ahead of the welding zone. In the welding zone, the granular material fuses and protects the weld from the effects of the atmosphere. Since the atmosphere is excluded from the weld, bare welding wire is used and can be fed directly into the welding zone. The molten mineral material removes impurities from the weld zone and, upon cooling, solidifies and forms a protective cover over the weld. When cool, the fused material cracks off or can be removed easily. The welds produced by the submerged-arc welding process are dense and uniform and are as strong as the parent metal or stronger.

Automatic Welding Fixture

To facilitate the use of the submerged-arc welding process, a special automatic welding fixture had to be developed which would be capable of allowing the submerged-arc welding machine access to the inside of the crankcase to produce the interior circumferential welds and also be capable of having horizontal and vertical movements in order to produce the necessary exterior welds. The automatic welding fixture finally developed is shown in Fig. 4.

To support the crankcase sub-assemblies while being welded and to revolve them at the proper speed necessary to produce good welding conditions, a power-driven turning roll was developed (Fig. 5). This roll was positioned adjacent to the welding fixture.

The automatic welding fixture employs a standard submerged-arc welding machine with an automatic welding wire feed control. The flux is fed from a storage hopper, positioned on top of the submerged-arc welding head, into a tube which has a small stoker screw, powered by a gear-head motor, revolving inside. As the screw revolves, flux is transferred through the tube and spills out at the weld point to keep the arc covered. The welding wire is first pushed by a wire-feed mechanism through a small tube for a distance of approximately 3½ ft and then through a bent copper nozzle (Fig. 4 inset). The copper nozzle bends the welding wire as it reaches the end of the straight tube and causes the wire to emerge reasonably straight from the nozzle tip and at the proper angle for it to enter the weld joint. Replaceable tips on the bent copper nozzle facilitate maintenance of this part. The bent portion of the nozzle is lined on the inside with a close-coiled steel spring which tends to reduce friction between the wire and the inside of the bent nozzle and, therefore, reduces the force required to push the wire through the long tube and the bent nozzle assembly. By keeping the friction force low, good arc-voltage control can be maintained, a necessary feature for producing predictable welds by the submerged-arc welding process.

The vertical movement of the welding fixture's head and ram assembly is affected by a lead screw driven by a reversing gear-head motor. The entire assembly is counterweighted to take the weight off the lead screw. The vertical mast, which supports the head and ram assembly, is pivotally mounted so that the entire welding-wire-feed apparatus and flux-feed apparatus can be positioned to cover a circular area. Both the wire-feed and flux-feed apparatus are attached to a slidably mounted ram which is power driven by a reversing gear-head motor working through a

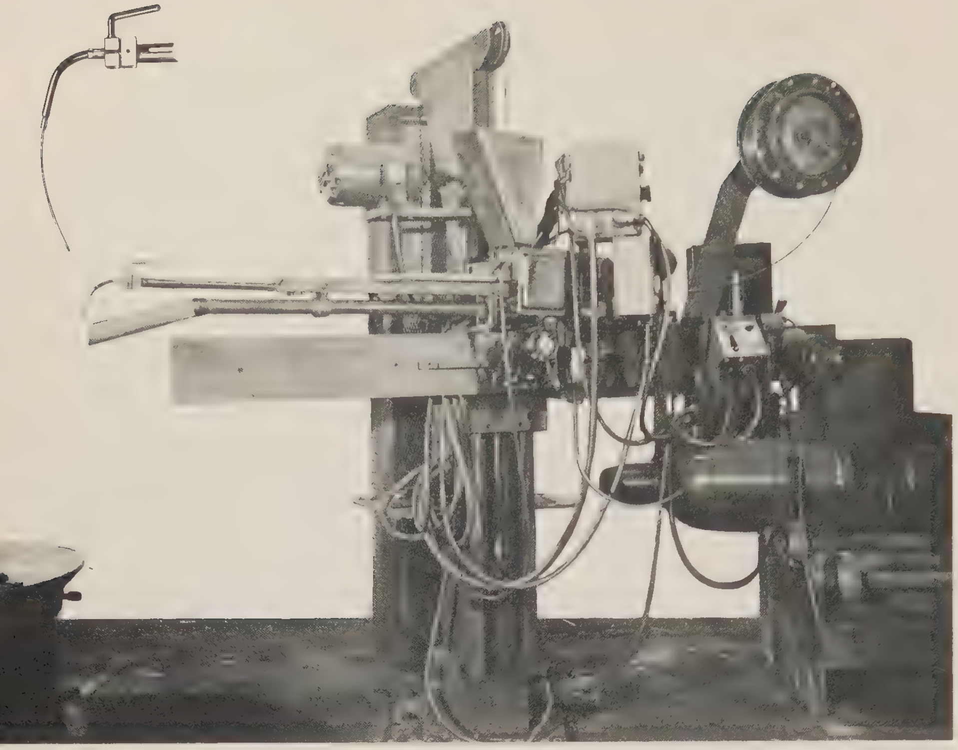


Fig. 4—A special welding fixture was developed to facilitate the use of the submerged-arc welding process for the welding of the crankcase sub-assemblies and final assembly. The fixture allows the submerged-arc welding machine head easy access to inside circumferential welding zones and also exterior welding zones. The flux necessary for the welding operation is fed from a storage hopper positioned on top of the welding head. By the use of a bent, copper nozzle (shown inset) the welding wire is assured of entering the weld joint at the proper angle.

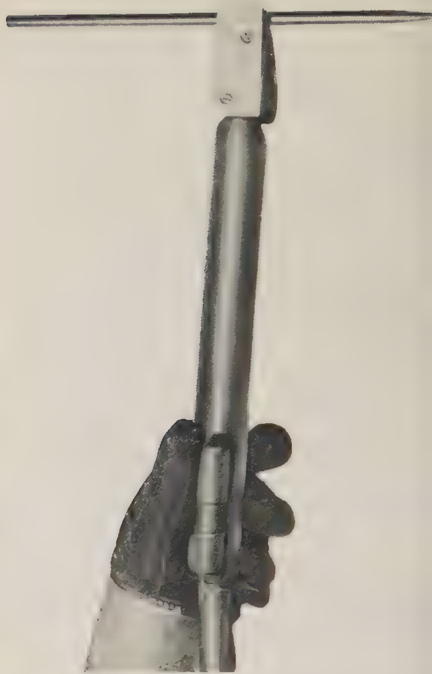


Fig. 6—The arc-air process of flame cutting, used in a majority of the required flame-cutting operations, employs a special torch which holds a carbon rod for striking an arc. When the arc has been established, and a puddle of molten metal is in the arc center, a jet of air directed into the puddle blows the molten metal and slag out of the crater. The jet of air is stopped by manually releasing an air-valve lever positioned on the side of the torch handle.

Fig. 5—Power-driven turning rolls, which revolve at the proper speed to produce good welding conditions, support the crankcase sub-assemblies while being welded. The rolls are positioned to the right of the submerged-arc welding fixture. The welding current is supplied by a 1,200 amp d-c motor-generator set shown in the background.

pinion gear and rack. The combination of these two motions, circular and radial, produces full coverage of the annular area between the minimum and maximum radius described by the tip of the bent copper nozzle.

There is an auxiliary movement between the wire-feed tube and the slidably mounted ram carrying the wire-feed and the flux-feed apparatus. The wire-feed tube assembly is pivotally mounted on a vertical pin. An extension of the wire-feed tube assembly beyond the pivot point carries a roller which acts as a cam follower. The roller engages a cam plate that is rigidly attached to the support of the slidably mounted ram and as the ram moves the roller follows the cam shape and causes the wire-feed nozzle to describe a circular path. This circular path is designed to be in agreement with the circular weld-joint design of the various sub-assemblies welded on this fixture. The welding current is supplied by a 1,200 amp d-c motor-generator set positioned behind the power-driven turning rolls and visible at the top of Fig. 5.

Fig. 7—The inner deck sub-assembly consists of four inner deck steel forgings welded together—each forging being identical to the individual piece shown. For small-lot production the forgings are manually arc-welded together and each tie-bar shown on the left of the individual piece remains in place. For volume production the tie-bars are removed and the individual forgings are flash butt-welded together. Four inner deck sub-assemblies are required for each completed crankcase.

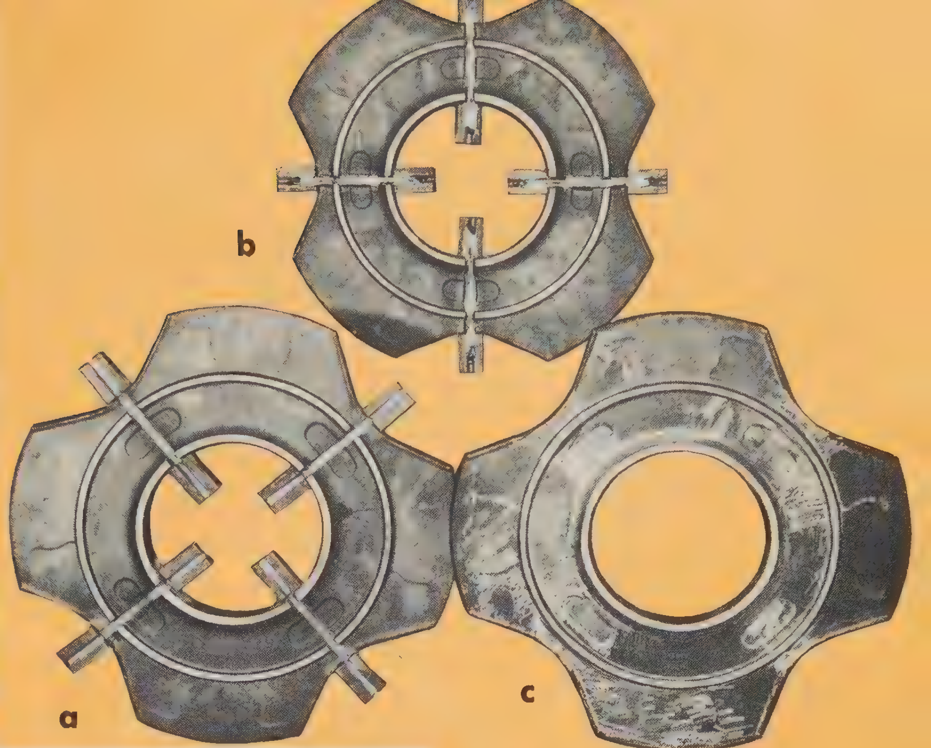


Fig. 9—The completed stress member sub-assembly consists of four identical steel forgings welded together by two different welding methods—flash butt-welding and submerged-arc welding. A burn-off allowance of 7/8 in. is allowed on each end of each forging when the flash butt-welding operation is used. When the stress member sub-assembly is fabricated by the submerged-arc welding operation, the individual forgings are first machined at the joints and tack-welded together. Then waster plates are attached *a*, and, finally, the piece is submerged-arc welded *b*. The waster plates are then removed by a flame-cutting operation to give the completed sub-assembly *c*. The view at the right shows the piece after it is machined and ready to be stacked.

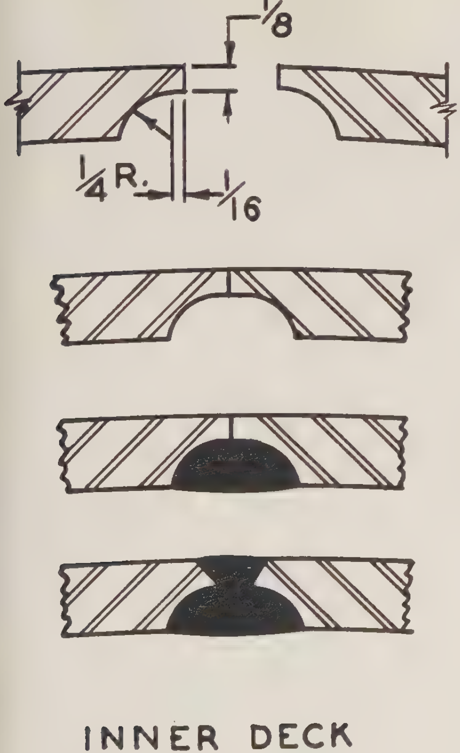


Fig. 8—There are four steps in producing this joint by the manual arc-welding method. First, the rough forgings must be machined at the joining edges. Second, the four pieces are brought together and tack-welded. Third, the channel (shown inverted) is filled in. Finally, the opposite side is welded to complete the procedure.

A study of the flame-cutting operation necessary for removing waster plates from various parts of the sub-assemblies showed that for greatest efficiency and ease of cutting, two methods could be used—the conventional oxy-acetylene process and the arc-air process, each process being used where its application proved most advantageous.

The arc-air process employs a special torch which holds a carbon rod for striking an arc (Fig. 6). When the arc is established and a puddle of molten metal is in the arc crater, a jet of air directed into this puddle blows the molten metal and slag out of the crater. The arc is maintained during the blowing period which lasts for only 1 or 2 sec of time. As soon as the air blast is stopped, by manually releasing an air-valve lever on the handle of the torch, a new puddle of molten metal is formed and is blown out of the crater by another blast of air from the jet. This process is repeated continuously until the metal-removing operation is completed. The arc-air process is easily controlled and is very rapid in its action. It has the advantage over manual flame cutting for removal of waster plates because it results in a much smoother and cleaner finished cut.

Fabrication Procedures

The procedures for the fabrication of the welded sub-assembly which are described below were finalized so that they would be satisfactory for either high-volume or small-lot production output.

Inner Deck Sub-Assembly

The inner deck sub-assembly consists of four inner deck steel forgings welded

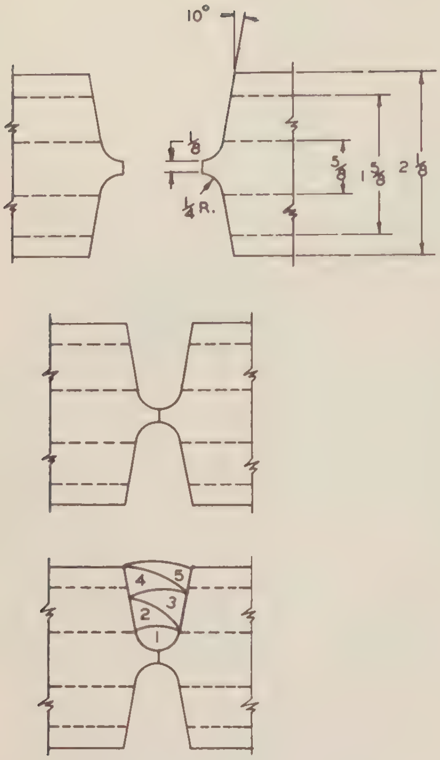


Fig. 10—Each stress member is machined for welding on its ends, as shown. The four pieces are assembled, aligned, and tack-welded. Then one channel is filled in by laying in five beads of weld metal successively. This operation, which is repeated on the opposite side, is known as *stringing* and interlaces the beads to obtain maximum strength and reduce the possibility of trapping slag in the weld metal.

together (Fig. 7). The fabrication procedure for this particular sub-assembly depends on whether the requirements call for high-volume or small-lot production.

If small-lot production is to take place, it has been found more economical to arc-weld the individual forgings together manually. In this instance the tie-bars, as shown in Fig. 7, resulting from the forging operation are left in place. The design of the weld joint, fit-up, and welding sequence for the manual arc-weld method are shown in Fig. 8.

When manual arc-welding is not used to fabricate the inner deck sub-assembly, the tie-bars are removed and the individual forgings are flash butt-welded together with a burn-off allowance of ⅝ in. on each end of each inner deck forging. After the flash butt-welding operation is completed, the sub-assembly is then stress-relieved. The welding flash is removed and, finally, the sub-assembly is machined on the ends to interlock with the stress members for ease in stacking.

Stress Members

The stress members of the engine crankcase are fabricated by two different methods—flash butt-welding and submerged-arc welding. In the flash butt-welding fabrication method, four identical steel forgings are flash butt-welded together to form the completed stress member sub-assembly (Fig. 9). The burn-off allowance for this operation is ⅞ in. on each end of each forging. After the forgings are flash butt-welded together, the sub-assembly is then stress-relieved and the flash removed. X-ray inspections follow to established standards, and finally the piece is machined to interlock with the inner deck rings.

When the stress members are fabricated by the submerged-arc welding process, the quarter sections are machined at the joints. Four of these are tack-welded together to make a complete ring. Then waster plates are attached. Finally, the four joints are submerged-arc welded together. The design of the weld joint, fit-up, and submerged-arc welding sequence are shown in Fig 10.

A special welding-head positioner is used when the stress member sub-assembly is fabricated by the submerged-arc welding process. A standard automatic submerged-arc welding head is mounted on a travel carriage that is self-propelled by an electric motor driving arrangement. This unit travels on a rail from left to right and must be returned manually to its starting point. The rail can be raised or lowered to suit the job height and the work is held on a standard tilting-rotating welding positioner. This special welding-head positioner is very versatile and can be used for many jobs in addition to the one indicated.

Outer Deck Sub-Assembly

The outer deck sub-assembly is fabricated from five identical steel forgings, flash butt-welded together end-to-end with no pre-machining (Fig. 11). The excess material left at each end is removed by conventional oxy-acetylene flame cutting. The entire sub-assembly is then stress-relieved and the "upset" flash trimmed off with an air-operated chipping hammer.

Fig. 12 shows the relationship between the outer deck sub-assembly and the stack-up sub-assembly. The flat surface on the side opposite the five ribs of the outer deck sub-assembly is machined to a layout and the five ribs are then bored to a 16-in. radius to match the spokes on the stress members in the welded stack-up sub-assembly. Four outer deck sub-assemblies are required for each completed crankcase.

Stack-Up Sub-Assembly

The stack-up sub-assembly, shown at the left in Fig. 12, consists of five stress member sub-assemblies and four inner deck sub-assemblies. These nine separate sub-assemblies, having a total of 36 individual steel forgings, are machined to nest together into a straight stack-up.

Angular alignments for the stack-up sub-assembly are assured by threading lining-up bars through four of the eight round holes of the stress members. The lining-up bars also serve as tie-bars to hold the individual stress member and inner deck sub-assemblies together while adjusting to provided layout lines and also when the entire stack-up sub-assembly is tack-welded. A final inspection is made of the tack-welded assembly to insure that all component parts are aligned properly so that all surfaces to be machined have sufficient clean-up stock.

When the final inspection of the tack-welded stack-up sub-assembly is complete, turning discs are bolted to each end of the sub-assembly. The turning discs support the stack-up sub-assembly on the power-driven positioning rolls used in conjunction with the submerged-arc welding machine.

The first automatic submerged-arc welding operation which takes place is the welding of the outer side of the eight circumferential joints of the stress member sub-assemblies to the inner deck sub-assemblies. The design of the weld joint, fit-up, and welding sequence for this operation are shown in Fig. 13. When the outside beads are completed, the tack-welds in the eight inside grooves are removed by the arc-air process and the inside grooves then filled with weld metal to complete the stack-up sub-assembly welding operation.

The submerged-arc welding operation is performed with a ⅛-in. diameter type-L-70 welding rod and a No. 50 flux (12 by 150 mesh). The outside beads are welded in one pass using 450 amp at 30 v d-c and a traverse rate of 24 in. per min. The inside beads are welded in

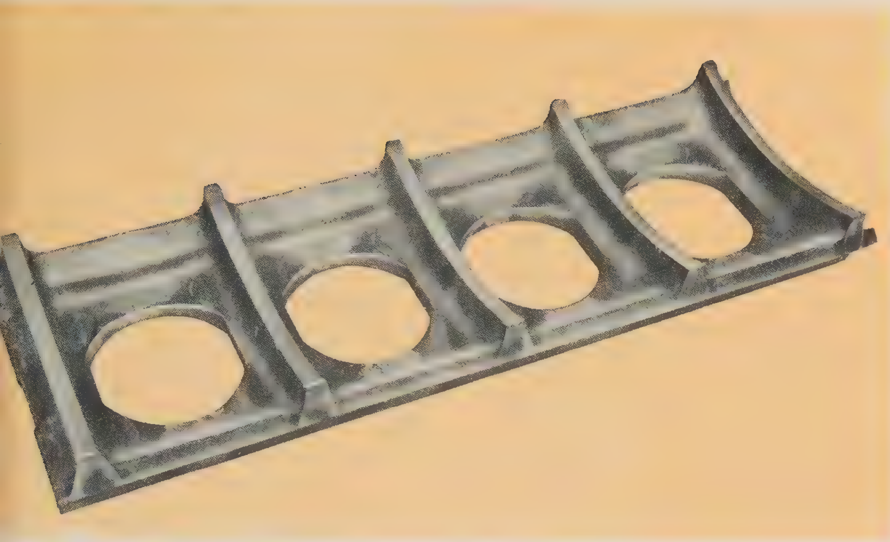


Fig. 11—The outer deck sub-assembly is fabricated from five identical steel forgings, flash butt-welded together end-to-end with no pre-machining. The excess material left at each end of the sub-assembly is removed by an oxy-acetylene flame-cutting operation. Four outer deck sub-assemblies are required for each completed crankcase assembly.

Fig. 12—Relationship between the outer deck sub-assembly (right) and the stack-up sub-assembly (left). The flat surface of the outer deck sub-assembly is machined and the five ribs bored to a 16-in. radius to match the spokes on the stress members in the stack-up sub-assembly. The stack-up sub-assembly consists of five stress members and four inner deck sub-assemblies which are machined to nest together into a straight stack-up.

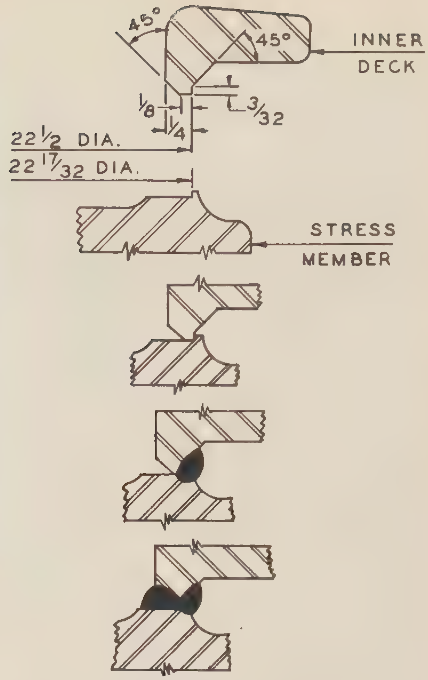
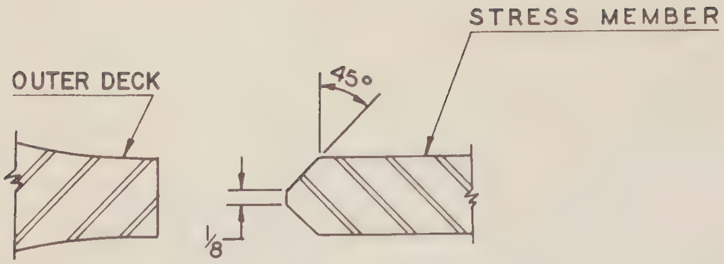


Fig. 13—The inner deck sub-assemblies and stress member sub-assemblies are machined to nest together for welding, as shown. The matching faces are chamfered to provide a place for the weld metal. The right-hand channel is first filled in with weld metal. The filling in of the left-hand channel with weld metal completes the welding procedure.

one pass using 650 amp at 38 v d-c and a traverse rate of 15 in. per min.

After the submerged-arc welds are completed they are cleaned and ground smooth and all defects excavated, repair welded, and magnaflux inspected until found to be sound. The completed stack-up sub-assembly is then machined to receive the four outer deck sub-assemblies. This requires that the spokes on the stress members be straightened and then machined to a diameter of 32 in. and chamfered on both sides at a 45° angle with a 1/8-in. wide, flat-nose tool. The design of the weld joint for the stress member, the fit-up between the stress member and the outer-deck, and the welding sequence are shown in Fig. 14. A sectional schematic view showing the location of all welded joints in the complete stack-up sub-assembly is shown in Fig. 15.

The four outer deck sub-assemblies are assembled to the stack-up sub-assembly by a special set-up and aligning fixture (Fig. 16). This fixture aligns and positions the mating parts so that they can be tack-welded together. From the set-up and aligning fixture, the tack-welded assembly is placed on a special indexing fixture for the submerged-arc welding of



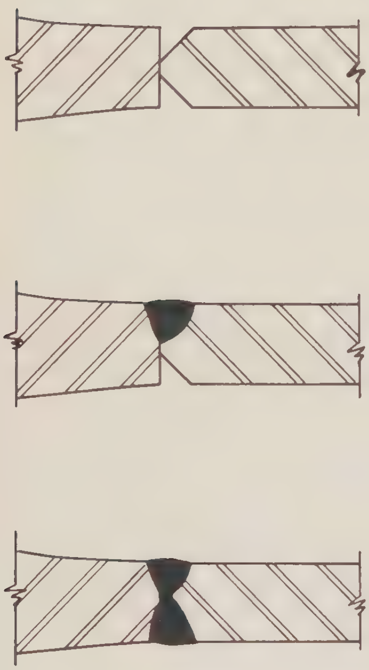


Fig. 14—The outer deck and stress member sub-assemblies are machined for welding, as shown. The matching faces are brought together and tack-welded. The top and bottom channels are then arc-welded.

the five rib joints on each of the outer decks (Fig. 17). Special waster plates are tack-welded at each of the joints so as to extend the joint about three inches beyond the ends of the machined weld grooves. This is done to give the welding machine operator an opportunity to stabilize the arc before it reaches the forgings and also to produce good clean weld metal all the way up to the edge of the forgings.

After all 20 of the outer deck's rib joints have been welded from the first side, by indexing the crankcase four times for each of the five rib elevations, the crankcase is turned end for end. The grooves are then back chipped down into the weld metal placed in the first side by using the arc-air process. The joints are magnafluxed and the welds completed on the second side.

When the welding is completed, the waster plates are removed either by conventional oxy-acetylene flame cutting or the arc-air process. The rough edges resulting from the flame-cutting operation are dressed up by a combination of grinding and manual arc welding until they blend into the forging contours to give the appearance of being one continuous piece. All welds are then ground smooth, magnafluxed, and X-ray inspected to established standards. A special set of positioning rolls similar to the power-driven rolls are used to provide easy access to all welds inside and outside of the weldment.

The crankcase fabrication is completed after the two flat end plates and filler plates, that frame the top and bottom edges of the large rectangular openings in the crankcase, have been manually arc-welded to the completed assembly. These particular joints are not heavily loaded and are magnaflux inspected only. The entire welded assembly is then stress-relieved, sand blasted, and finally machined.

Machining Operations

A definite machining sequence was established which utilizes standard and special equipment and fixtures.

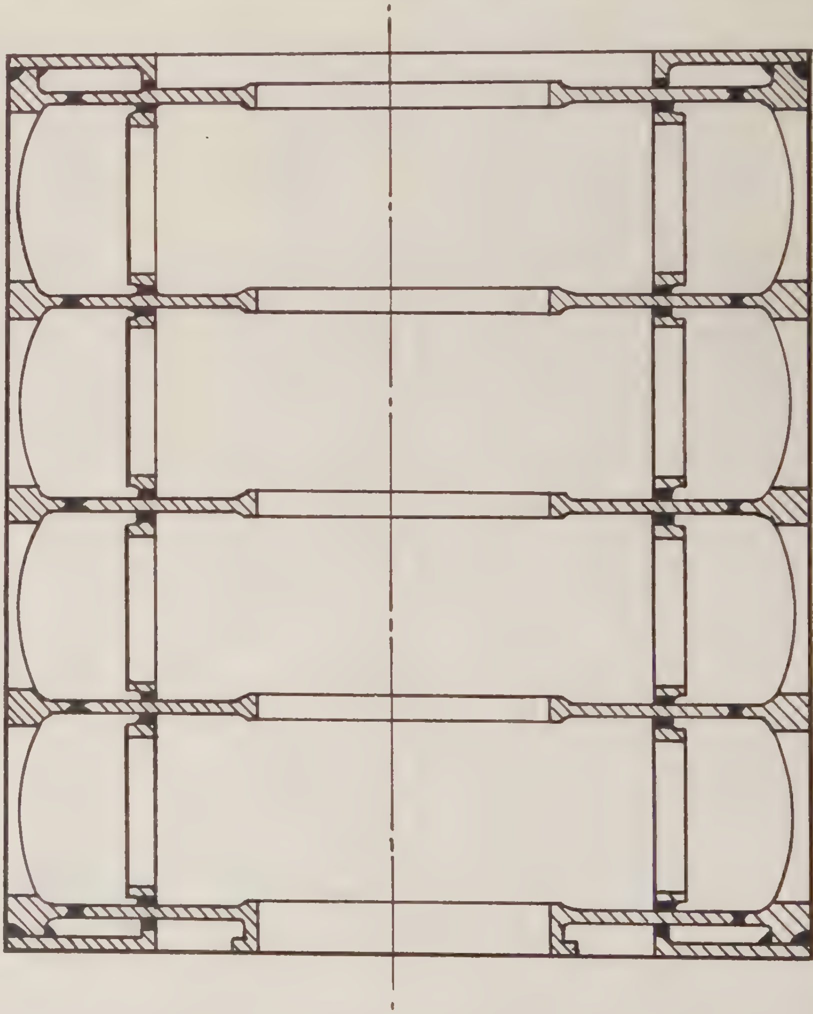
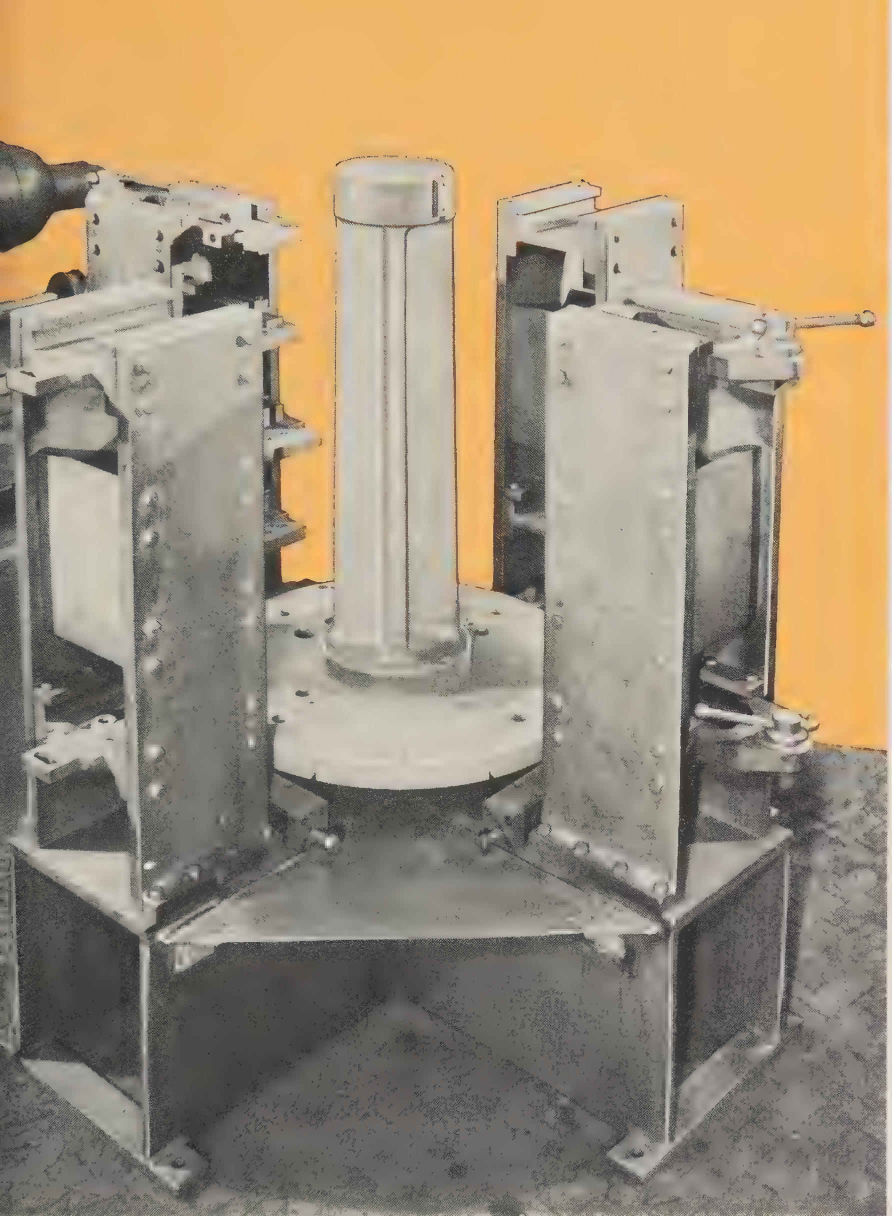


Fig. 15—The fabrication of the crankcase is completed after three major welding operations have been performed. The first operation is the submerged-arc welding of the stress member sub-assemblies to the inner deck sub-assemblies. These two sub-assemblies constitute the stack-up sub-assembly. The four outer deck sub-assemblies are then submerged-arc welded to the stack-up sub-assembly. Lastly, two flat end plates and filler plates, which frame the top and bottom edges of the large rectangular openings in the crankcase, are manually arc-welded to the completed assembly.



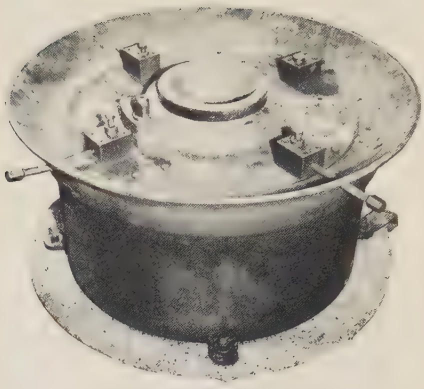


Fig. 17—A special indexing fixture holds the tack-welded outer deck and stack-up sub-assemblies during the submerged-arc welding of the five rib joints on each of the outer decks to the stack-up sub-assembly. When the welding operation is completed for the first five rib joints, the entire assembly is then rotated in the fixture, re-indexed, and the welding operation repeated. The assembly is then turned end for end on this fixture and the welds on the rib joints are completed on the opposite side. The position of this indexing fixture with relation to the welding machine is partially illustrated in Fig. 4.

Fig. 16—A special set-up and aligning fixture is used to aid in tack welding the four outer deck sub-assemblies to the stack-up sub-assembly. The tack-welding operation precedes the final submerged-arc welding operation.

The first machining operation is the boring and facing of both sides of each of the five main-bearing bores and facing the ends on a 72-in. vertical boring mill. The next machining operation is the milling of the four outer deck surfaces, the four faces between and at 45° with the outer decks, and the eight inner hand-hole cover faces on horizontal boring mills. The five main-bearing bores are then ground on a large internal planetary grinder. Circular slots are milled in the main-bearing bores in order to accommodate the main-bearing carrier keys. Next, dowel holes are drilled and reamed in the main-bearing bores for the main-bearing carrier dowels. This operation requires a special right-angle attachment for use on a horizontal boring mill. The 16 cylinder holes are bored with the crankcase mounted on a special rotary table and on a special height horizontal boring mill. Drilling, reaming, and tapping then takes place in all machined faces. A particularly difficult machining operation consists of forming spherical seats for the heads of cylinder-head hold-down bolts using inverted-type spot facing tools.

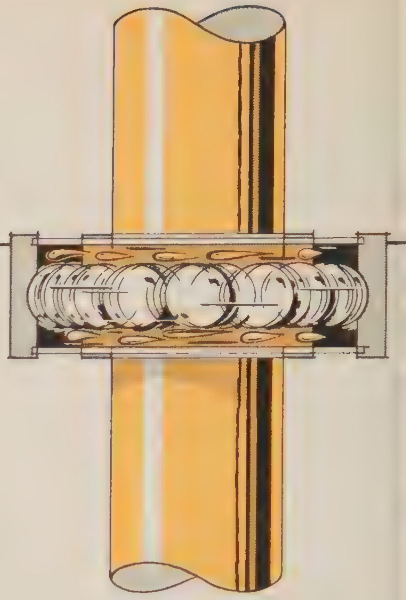
Summary

The use of the automatic submerged-arc welding process on this high-speed Diesel engine crankcase has reduced the overall welding cost by reducing the amount of repair work required to pass X-ray inspection.

As in all manufacturing operations, continued developmental work has been undertaken to improve the fabrication procedure connected with the assembly of the crankcase sub-assemblies. It has been found that flash butt-welding of the four segments of the stress member can be eliminated by making the stress member a one-piece forging resulting in further cost savings. The flash butt-welding of the five small forgings which now make up the outer deck sub-assembly also can be eliminated by making this part a one-piece forging. Such changes would eliminate all flash butt-welded joints on the crankcase. The stress member and the outer deck sub-assemblies would have been designed as one-piece forgings at the start of this project if there had been facilities available to die forge such large pieces.

The automatic submerged-arc welding process which has been applied successfully to the fabrication of the vertical, light-weight, two-cycle Diesel engine also is used for many other parts in the general manufacturing area at the Cleveland Diesel Engine Division. It is used to fabricate cylinder liners, pistons, cylinders, larger and smaller crankcases made of boron steel forgings, generator frames, pole pieces for generators, and gas bottles.

Empirical Methods Developed to Forecast Life of Self-enclosed, Grease-lubricated Ball Bearings



Since 1908, when New Departure Division entered the development and manufacture of the ball bearing, its engineers have worked on the evolution of better ball bearing lubricants—lubricants that would provide a film between balls and separator, allowing them to slide across one another with a minimum of friction; that would dissipate heat caused by friction; and that would provide a film on the load carrying surfaces and prevent rust and corrosion. With the marked trend in recent years toward the preference of the self-sealed and self-lubricated bearing, the need for a grease having such properties has become acute. The growing popularity of the self-lubricated bearing stems from its ability to perform functions ordinarily requiring an open bearing, an intricate lubrication system, and a set of external sealing members. Shielded and sealed bearings are lubricated for life at the time of manufacture. Consequently, it has become increasingly important to select the best possible grease to be used in this type of bearing and, moreover, to predict accurately the performance of the lubricant selected.

SINCE New Departure Division first developed a completely self-enclosed ball bearing, a major problem has been the development of a grease which would have a longer operating life than the other bearing components, while functioning under the greatest possible variety of working conditions. The main function of the grease, as that of any ball bearing lubricant, is to provide a lubricating film between contacting surfaces of balls, races, and separator (Fig. 1).

Sealed or shielded bearing life is determined by any one of several principal factors: fatigue life, separator life, effective seal life, and effective lubricant life. Fatigue is generally the limiting factor when the bearing is subjected to continued heavy loading and lubrication is adequate. Separator failure generally results from high speeds or severe bearing misalignment. If sealing is a major difficulty, the entry of foreign matter may be the cause of failure. In cases where loading is moderate to light and sealing is adequate, the life of the grease lubricant is the determinant.

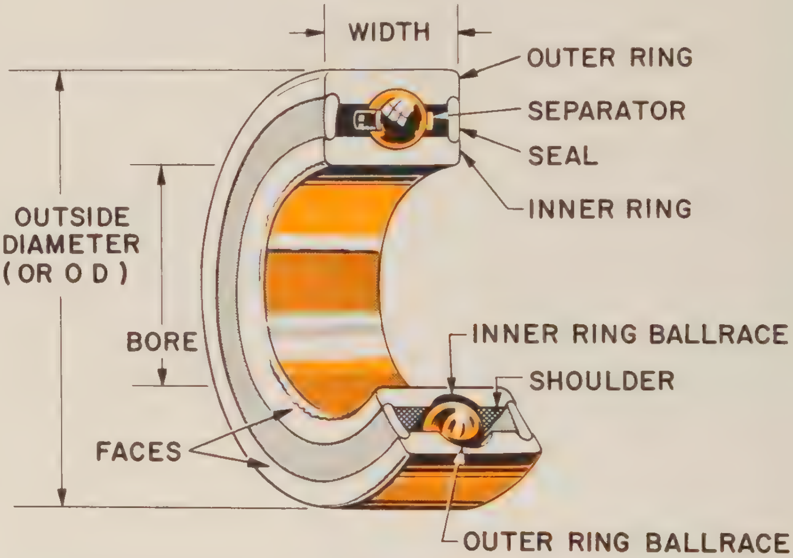


Fig. 1—The principal components of a sealed or shielded ball bearing are identified in this sketch. Grease provides a lubricating film between the contacting surfaces of the balls, races, and separator.

Method of Grease Breakdown

Grease is fundamentally a mixture of a base fluid, a thickener, and suitable additives. The base fluid, which is ordinarily a mineral oil (although it may be a synthetic material), is the lubricating medium; the thickener, usually a metallic soap, acts as a medium to store the oil and to release it as needed; the additives serve to enhance such properties as load carrying capacity, corrosion protection, and oxidation resistance of the lubricating fluid.

The mineral oils or suitable synthetic materials used in grease manufacture generally contain compounds with varying degrees of chemical stability. In operation, the less stable compounds usually react more rapidly with the oxygen in the air to form products detrimental to bearing performance. The greater the degree of oil refinement, the fewer there are of these relatively unstable compounds present. However, after they break down, the more stable compounds become oxidized and polymerized. This proceeds at a much slower rate than with the less stable compounds but, as it takes place, heavy tars and sludges are formed which eventually render the grease incapable of supplying a lubricating film. When this point has been reached, the grease is at the end of its lubricating life and bearing failure results.

A major goal, therefore, has been the

By HARRY D. MARTIN and

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Applying the effects of speed, load, and temperature to greased bearing life

development of a grease with the slowest possible oxidation rate. Since the first years of pre-packed bearings, a large number of greases has been investigated with this goal uppermost on the list of requirements and many greases have been developed through joint efforts with the petroleum industry. A direct result of these labors was the formulation of a proven general-purpose ball bearing lubricant, New Departure Code C grease, which now has been in use for many years.

Another result was the accumulation of a vast amount of data and experience which has been extremely helpful in guiding the thinking of the Division's ball bearing engineers toward the optimum utilization of available lubricants and in the continuing search for better ones.

Relation of Heat to Grease Life

A most important conclusion drawn from the early work in the ball bearing lubricant field is that grease life is mainly dependent upon the bearing temperature, varying inversely with the temperature at the points of lubrication (the contact points between balls, races, and separator). This is in line with the present knowledge of the general effect of temperature on chemical reactions. The actual relationship of grease life to bearing temperature was found to be a straight-line plot on a semi-logarithmic scale, according to the general equation:

$$B = c \times 10^{mT}$$

where

- B = base grease life (hr)
- T = bearing outer race temperature (°F)
- c and m are constants which reflect the oxidation characteristics of the grease and which determine the slope and location of the line.

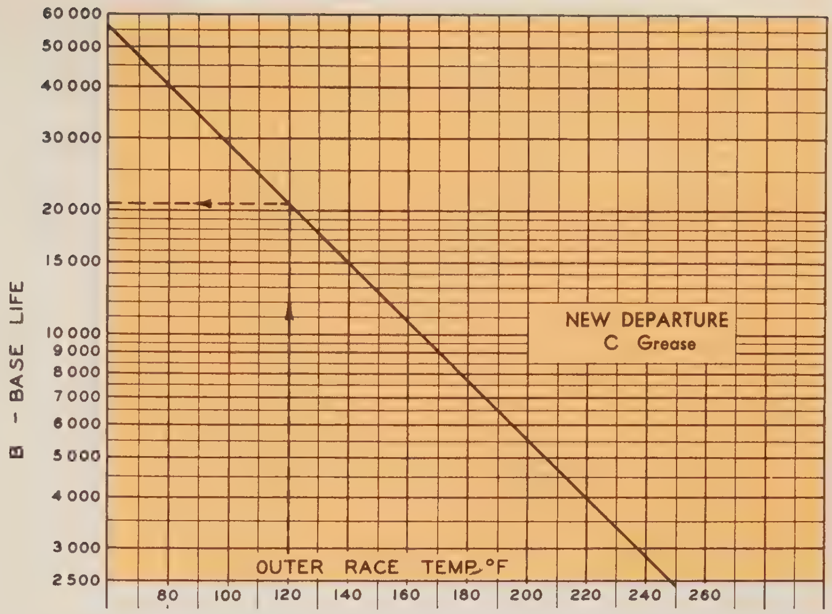


Fig. 2—Early laboratory and field work indicated that base grease life B is dependent upon bearing temperature T, varying inversely with the temperature at the points of lubrication (contact points between balls, races, and separator), according to the general equation: $B = c \times 10^{mT}$ where c and m are constants. This curve is for single row, radial, non-loading groove bearings, operating at 3,000 rpm, with a negligible load, and one-fourth full standard pack of the standard New Departure Code C grease.

From laboratory and field data such a curve was constructed for single row, radial, non-loading groove bearings operating at 3,000 rpm, with a negligible load, and one-quarter full (standard pack) of the standard Code C grease (Fig. 2).

Bearing temperature, as studied in a practical grease test fixture, is measured on the stationary members (outer race) as close as possible to the point of maximum load. As this point is usually on the periphery OD of the outer ring, the relationship of measured bearing temperature to grease life unfortunately is not always as previously described. The reason for this is that the actual temperature of the working grease does not have any absolute relationship to the temperature of the bearing OD, but

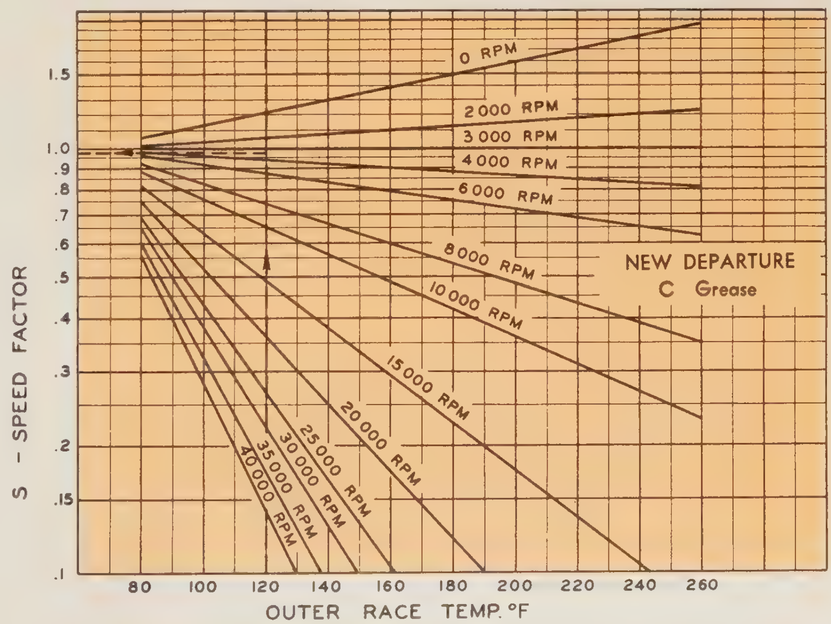


Fig. 3—The effect of speed on grease life was tested using Code C grease with single row, radial, non-loading groove bearings, operating at various ambient temperatures and speeds. The results established that, with a given bearing and a given outer race temperature, higher speed means reduced grease life. From the above curves, the speed factor S can be determined for use in the formula for forecasting grease life.

Table I (Right)—An early step in determining effect of load upon grease life is to find the equivalent radial load on the bearing. First, the ratio of applied thrust load to radial load is found (thrust load/radial load) and this value is multiplied by the conversion factor A. This conversion factor is determined experimentally and varies with the bearing type and the T/R ratio. This table lists values of A for single row, radial, non-loading groove, New Departure Code C greased bearings.

CONVERSION FACTORS FOR EQUIVALENT RADIAL LOAD COMPUTATION

Thrust Load/Radial Load	0	0.05	0.10	0.2	0.4	0.6	0.8	1.0	2.0
Conversion Factor A	1.0	1.13	1.30	1.62	2.1	2.6	3.0	3.3	5.2
Thrust Load/Radial Load	4.0	6.0	8.0	Pure Thrust					
Conversion Factor A	8.8	12.7	16.8	*2.1					

*For pure thrust and T/R values greater than 8, multiply the thrust component by 2.1.

INTERMEDIATE FACTOR (I)

Light Section Bearing Series (By Bore Number)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.9	14	18	24	38	62	89	148	229	315	391	468	643	855	1,145	1,320	1,865	2,965	4,320
0.8	31	40	53	83	135	193	323	500	686	852	1,020	1,400	1,860	2,500	2,875	4,070	6,460	9,400
0.7	49	63	83	129	212	302	507	785	1,075	1,340	1,600	2,200	3,920	3,930	4,520	6,380	10,130	14,780
0.6	71	91	119	185	305	437	730	1,125	1,545	1,920	2,300	3,160	4,200	5,630	6,470	9,160	14,550	21,200
0.5	96	123	162	252	414	593	990	1,530	2,100	2,605	3,120	4,280	5,700	7,650	8,800	12,420	19,750	28,800
0.4	128	164	216	336	552	790	1,320	2,040	2,800	3,480	4,170	5,720	7,620	10,180	11,720	16,600	26,400	38,400
0.3	166	213	281	437	718	1,020	1,710	2,650	3,640	4,520	5,400	7,440	9,780	13,200	15,250	21,600	34,300	49,800
0.2	224	287	378	587	967	1,380	2,310	3,570	4,900	6,090	7,290	10,000	13,300	17,850	20,500	28,000	46,200	67,200
0.1	320	410	540	840	1,380	1,975	3,300	5,100	7,000	8,700	10,400	14,300	19,000	25,500	29,300	41,500	66,000	96,000
0.05	416	532	702	1,090	1,790	2,565	4,280	6,630	9,100	11,300	13,500	18,600	24,700	33,100	38,100	54,000	85,700	147,500

Table II—The modifying load-speed factor F used in solving the formula for forecasting grease life is found from calculated data arranged in tabular form for various types of bearings. The intermediate factor I is first obtained from the charts in Fig. 4. The value of this factor is then located in this table from which the modifying load-speed factor F is found in the column at the left. This table, representing only a portion of the complete tables, contains the applicable values for single row, radial, non-loading groove bearings, light section series, one-quarter full of Code C grease.

PERCENTAGE-FAILED COMPARISON

Per Cent Average Life		10	20	40	60	80	100
Per cent of group of bearings to exceed per cent average life	Code C grease	100	100	96	80	63	46
	Fatigue	95	90	75	60	50	38

Table III—A further check of Code C grease is made by comparing percentage-failed figures with average grease life and bearing fatigue life.

rather depends upon the location of the heat source or sources. To illustrate, if the main heat source is external to the bearing and if grease shear and rolling friction are almost nonexistent, OD and contact temperatures will tend toward equality. If, on the other hand, the bearing, by virtue of high loads, speeds, seal friction, and/or grease friction, is itself a source of considerable heat and if the housing is a good thermal conductor, a vast difference can exist between the temperature of the lubricant film and the measured bearing OD temperature.

Since it has been found impossible to obtain directly the precise temperatures of the contact points, grease life forecasting has been based mainly on the following factors:

- Establishment of location and slope of the grease life versus measured temperature plot from actual test data
- Determination of the effect of the location and the nature of the heat source upon this plot by additional data regarding the speed and load testing of greased bearings
- Determination of the effect of bearing size and shaft and housing characteristics upon grease life, for example, how well heat can be conducted away from the critical area. (In this regard, it is generally true that the larger the bearing size the better the grease life from the viewpoints of load carrying ability and heat dispersion from its increased surface area. On the other hand, with high rotating speeds rpm, large bearing size would tend to reduce grease life by virtue of the greater amount of heat produced by the higher bearing peripheral speeds fpm).

Shaft and housing designs are probably the most important factors in the determination of rate of heat transfer from bearings, but their effect on grease life is largely reflected in the measured bearing temperature.

Theoretical and Practical Effect of Speed and Load on Grease Life

The foregoing discussion has summarized briefly both the effects of external heat and heat dispersion on the grease life versus the outer ring temperature plot. To understand the effects of internal heating due to speed and load it is necessary to consider each factor independently.

Effect of Speed

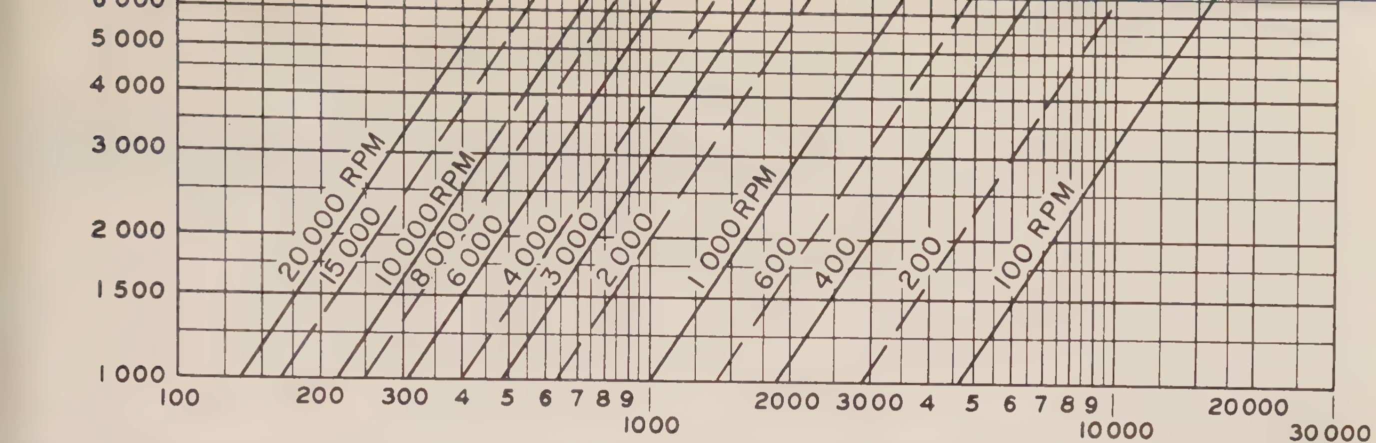
The formula for forecasting grease life states:

$$L_G = BSF$$

where

L_G = average grease life (hr)
B = base life (hr)
S = speed factor
F = load-speed factor.

In both theory and practice it has been established that, with a given bearing and a given outer ring temperature, higher speed means reduced grease life. Results of laboratory testing have also demonstrated that at higher temperatures this effect is proportionately pro-



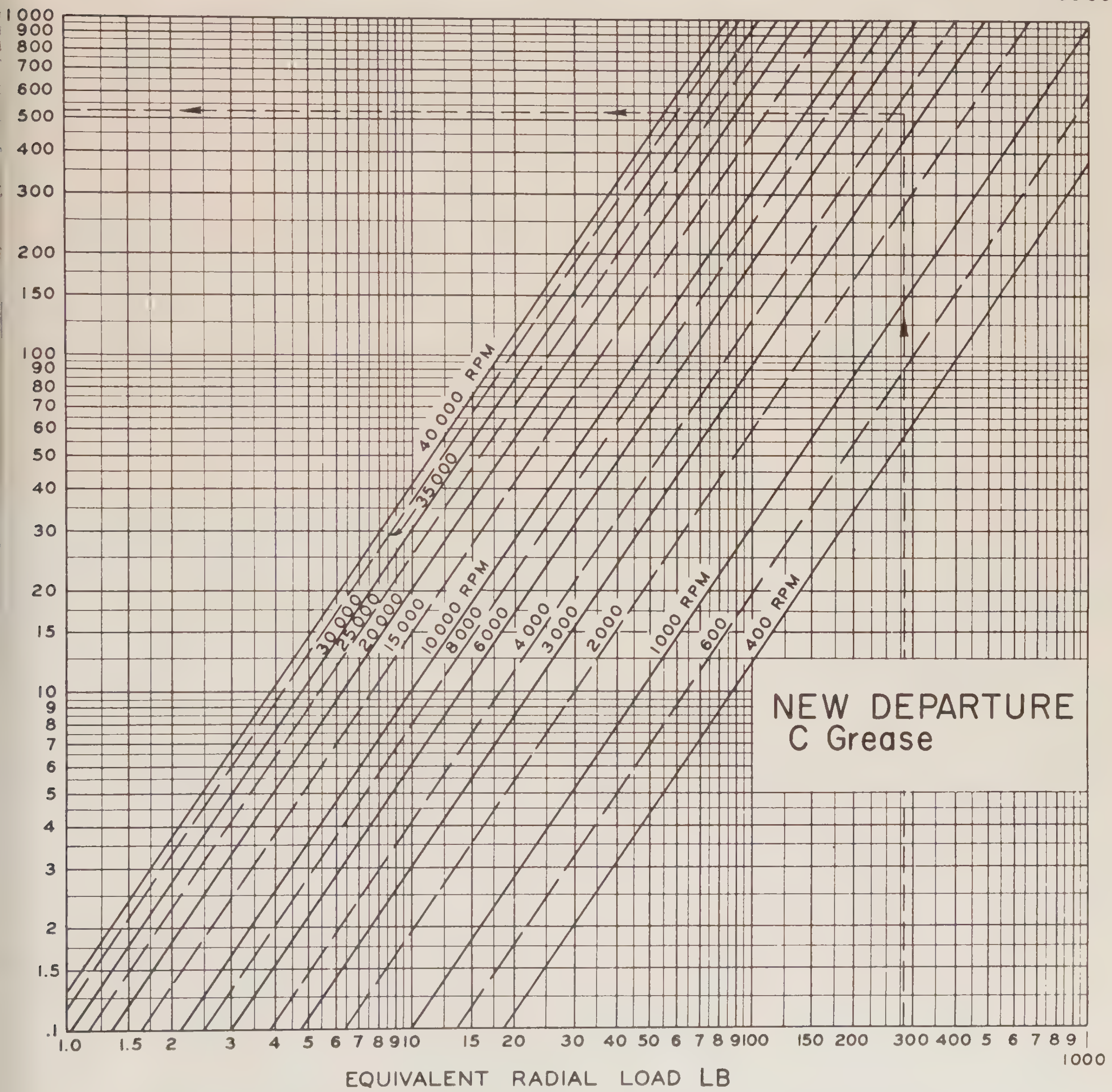


Fig. 4—Typical charts used in determining the effect of load on grease life. After the equivalent radial load is found (Table I), the intermediate factor *I* is determined from these charts. This factor is then used in conjunction with Table II to calculate the modifying load-speed factor *F*, required in solving the formula for forecasting grease life. These charts were compiled for single row, radial, non-loading groove, New Departure Code C greased bearings.

TEST CONDITIONS

Size	Outer Race Temperature	Inner Race (rpm)	Load (lb)	Test Life (hr)	Forecast Life (hr)
7107*	70-85° F**	10,000**	0	54,000+	32,000-48,000
77R4*	70-85**	300**	0	35,000+	37,000-66,000
97037*	100	1,200	0	36,000	32,000
97037*	180	1,200	0	13,200	9,500
87500	140	25,500	10 Thrust	1,820	1,420
88503	250	3,000	0	2,150	2,400
88503	250	10,000	0	450	600
88503	105	3,000	220 Radial	10,770+	11,320
88503	246	3,000	220 Radial	1,284	1,180
99505	122	3,000	525 Radial	4,700	5,000
88507	116	3,000	580 Radial	9,650	13,220
88507	141	3,000	1,060 Radial	4,320	3,300
88507	158	3,000	1,400 Radial	1,447	1,210
88508	91	2,000	100	34,000	32,200
77508	250**	3,000**	450 Thrust	250	980
3312	212	1,800	150 Radial	4,000+	5,320
1316	80-120	1,000-3,000	0-3,000	41,000+	15,000-41,000
1813	80-120	1,000-3,000	0-3,000	41,000+	15,000-41,000

*Field Tests **Outer Race Rotated—Inner Race Temperature

Table IV—The accuracy of the method of forecasting grease life is determined by field and laboratory tests. This table compares test life and forecasted life of grease under various bearing conditions. One conclusion which is evident from these data is that outer ring rotation causes variations from a forecast based strictly upon inner ring rotation.

nounced. From the measurement of the lives of single row, radial, non-loading groove bearings, operating at various ambient temperatures and speeds with standard Code C grease lubrication, the curves shown in Fig. 3 were obtained.

The same data disclosed that bearing size has a negligible effect on this plot. This fact may seem, at first, to be out-of-line with the previous thought that larger bearings tend to penalize grease life at high rotating speeds but, as also previously stated, the counterbalancing effect of added bearing surface area is present in larger bearings—the overall effect appearing to be an even balance.

Effect of Load

Determination of the effect of load on grease life is a more complicated procedure since load must be considered in relation to bearing size and speed. It is also important to consider what portion of the load is radial and what portion is thrust.

The first step in calculating the effect of load on grease life is the same as for fatigue life, namely, converting radial and thrust loading into *equivalent radial load* (that radial load which would give the same average bearing life as the actual existing combination of radial and thrust loads). The T/R (thrust load component divided by radial load component) must be obtained and then multiplied by a conversion factor which varies with the T/R ratio and bearing type and must be determined experimentally. For single row, radial, non-loading groove, Code C greased bearings, the values for conversion factors are shown in Table I.

Likewise important when considering the effect of load are two basic relationships: (a) that friction (rolling) torque varies as $(\text{load})^n$ and that, therefore, (b) heat, so generated, varies as $(\text{load})^n$ multiplied by speed in revolutions per minute. Therefore, for a given fixed OD temperature, the temperature differential from the bearing race should be proportional to the quantity $(load)^n \times rpm$ and grease life should vary inversely. Having established this relationship and also having accumulated the necessary data to guide in the determination of the n value, it is possible to arrange the evidence in chart and tabular form which can be used to determine the effect of load on grease life. For single row, radial, non-loading groove bearings, one-quarter full of standard Code C grease, such charts and tables have been prepared and are shown in Fig. 4 and in Table II.

Knowing bearing size, speed, and equivalent radial load, it is necessary to consult the chart (Fig. 4) for an intermediate factor I which, with the use of Table II, gives the modifying load-speed factor F.

Application of Code C Grease Life Forecast Method

To best illustrate the use of the tables and curves mentioned in the previous discussion, a sample set of operating conditions can be assumed and the average life of the ball bearing grease calculated. Suppose a shielded (or sealed) No. 8 bore, light section series bearing was to be operated one-quarter full of Code C grease at a speed of 4,000 rpm, under loads of 200-lb radial and 160-lb thrust, and at an ambient temperature such that the bearing OD temperature was observed to level off at 220° F. Then the average grease life L_G would be calculated as follows:

$$L_G = BSF$$

where

B, for a 220° F outer race temperature, equals 4,000 hr as determined from Fig. 2

S, for 220° F, 4,000 rpm, equals 0.84 as determined from Fig. 3

F equals 0.55, as determined from the following calculations.

The first step in the calculation of the factor F requires the selection of a conversion factor for the applicable T/R

value as determined from Table I. The conversion factor of 3.0 for a T/R value of 0.8 means that the equivalent radial load (based on grease life) equals 3.0 multiplied by 200 lb, or 600 lb. From Fig. 4 (top) an intermediate factor I is found as 1,800. Referring this value to Table II, the load-speed factor F is found to be 0.55. Therefore, substituting in the equation for average grease life, the forecasted grease life is:

$$L_G = (4{,}000)\ (0.84)\ (0.55)$$

$$L_G = 1{,}850 \text{ hr.}$$

The average grease life then should be compared to the normal bearing fatigue life. Using New Departure's fatigue formula:

$$L_f = 3{,}800\ (R_R/R_E)^4$$

where:

L_f = bearing fatigue life

R_R = load rating based on bearing fatigue action

R_E = equivalent radial load based on bearing fatigue action.

Note: Loading ratings and methods for calculating R_E and L_f may be found in the *New Departure Handbook, Vol. I.*

Substituting the numerical value of R_R/R_E (as found in the *Handbook*) in the above formula, the fatigue life of the bearing is:

$$L_f = 3{,}800\ (3.6)^4 = 360{,}000 \text{ hr.}$$

A comparison of the fatigue life of the bearing with that of the grease demonstrates clearly that the calculated grease life is the limiting factor.

To round out this comparison for Code C grease, Table III demonstrates the percentage-failed figures for various percentages of calculated average grease and fatigue lives. These percentages are important to consider, especially when grease and fatigue lives are relatively close.

Limitation of the Forecast Method

To maintain a proper perspective in regard to the grease life forecast method, it must be appreciated that results would not be 100 per cent accurate, even if all the conditions allowed for were exactly as stated. Table IV gives some indication of how grease forecast lives compare with actual grease lives in the field and in the laboratory.

This table also points out that outer ring rotation is a factor which causes variations from the forecast which was based strictly on inner ring rotation. An applicable rule of thumb is that, at low speeds and at near room temperatures, outer ring rotation has little effect, but it may reduce life to 50 per cent or less of that calculated for bearings operating at moderate to high speeds, with temperatures around 250° F and with inner ring rotation. This is based on available field experience.

Other important factors which have effects on grease life contradictory to those considered in the foregoing discussion are bearing types other than the single row, radial, non-loading groove variety, and race curvatures which do not correspond with 51.6 per cent inner ring and 53 per cent outer ring.

The effect on grease life of other bearing types, such as single row, radial, loading groove series, single row, angular contact series, and double row series, can be summarized as follows:

- Single row, loading groove series bearings, by virtue of their greater number of balls to share the load, can be expected to give greater grease life.
- Single row angular contact bearings under small load angles can be expected to give approximate agreement on grease life with that of single row, radial, non-loading groove bearings since the larger number of balls tends to compensate for the adverse effect of the contact angle on the ball loads. The combination of greater contact angles and large load angles has the effect of reducing ball loads and, therefore, longer grease life may be expected than that for radial bearings.
- Double row bearings, under small load angles, would be expected to give substantially longer grease life due to a more favorable distribution of load occurring with the two rows of balls. Under large load angles, although one row carries the majority of the load, longer grease life can be expected since the high contact angle serves to reduce the ball loads.

The effect of race curvatures on grease life is negligible under negligible load. Under load, however, friction is increased by close curvatures and decreased by open curvatures—the length of service life varying accordingly.

A further valuable application of the grease life forecast is the determination of the intervals between relubrication of Code C greased bearings. The term *relubrication* implies addition of small amounts of oil to partially oxidized grease in operating bearings—a practice which has been found to give extended life in certain applications. It has been determined that an interval of 40 per cent of forecasted life should be specified between relubrication injections, this figure having been chosen to minimize failure possibilities and, at the same time, to allow for extensive time periods between servicing.

Conclusion

It has been demonstrated that, with a relatively limited amount of data, it is possible to predict, with some certainty, the life of a bearing whose limiting factor is the grease upon which it depends for lubrication.

To review briefly the forecast procedure: under any condition where operating temperature, load, speed, and bearing size are known and where the bearing is of the single row, radial, non-loading groove, Code C greased variety, necessary steps in the prediction of its life are as follows:

(a) Obtain the basic life of the grease from the base life chart (Fig. 2)

(b) Determine the effect of speed by multiplying the base life by the speed factor taken from Fig. 3

(c) Determine the effect of load by multiplying the resulting figure of steps (a) and (b) by the appropriate load modifying factor according to the steps outlined in that portion of the text of this paper.

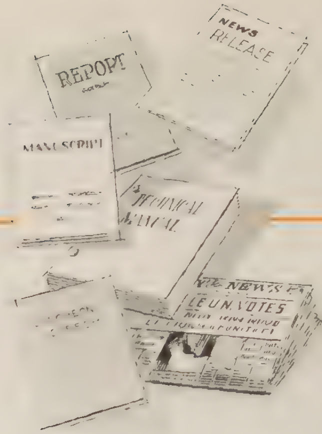
Availability of Related New Departure Literature

Copies of the pamphlet *Lubrication Life Forecast and Test Procedure for Integrally Sealed and Shielded Ball Bearings* and of the catalogue *New Departure Handbook, Volume I* may be obtained by writing to

New Departure Division
General Motors Corp.
Bristol, Connecticut.

The pamphlet contains material on which this article has been largely based and the handbook provides the data necessary for the selection and application of ball bearings for general use.

Reading Improvement in Industry Aided by Scientific Program



Developmental reading training, as a phase of the total communications training process, is a relatively new area in executive development. The need for such training is rather obvious in view of the mass of required reading of the executive. The engineer-executive, in particular, has a large volume of reading material which he himself must cover in order to keep up with new developments, trends, and research in his professional field of specialization. Ineffectiveness in his reading, either because of a slow rate, or inadequate vocabulary, or because he has not developed certain of the higher level reading skills required on his job, is a definite handicap. To help promote faster, more comprehensive, and more retentive reading skills for executives, industrial programs for reading training have been established. In General Motors, preliminary research and experimentation pointed the way to a program which took into account both physical and psychological factors affecting the reading process. This program has been in operation a relatively short time but already is showing concrete results. In one group, for example, the average executive was found to have a reading efficiency index of 191; however, after the group completed the reading improvement program, this index increased to 380.

READING is an extremely complex skill which involves coordination of the process of seeing the symbols on the printed page with the assimilation and interpretation of those symbols. Several factors affect the ability of any individual in his reading. These include concentration, eye movements, comprehension, reading habits, motivation and attitude toward reading, and, to some extent, intelligence and personality.

Here, a lesson applicable to the reading process might be taken from time and motion studies. Even the best self-taught athlete develops only low levels of skill compared to those which can be designed and taught by experts. Similarly, the industrial executive often has many self-developed and inefficient reading skills. The modern engineer, in most cases, has not received adequate training in efficient silent reading skills beyond the sixth grade level, because the majority of school systems did not teach new reading skills beyond this grade. Consequently, as he progressed through high school and college, he was forced to read more difficult materials with skills geared to the elementary level. As the new materials appeared, it became necessary for him to adjust to them by a trial-and-error process. Reading problems continue and often are accentuated after the executive is on the job, as is witnessed by the continual comments of being overburdened with reading tasks.

The armed services were among the first to recognize the lack of reading ability among adults and promptly attempted to compensate for it by means of developmental training programs in reading for their officers. Some industrial concerns are now conducting or sponsoring courses in reading for their executives, and the results in most cases have been extremely gratifying. The majority of industrial programs are based on design and research conducted with college students. Although basic principles and methods used with students are equally applicable to executives, some consideration must be made in view of different levels of maturity, interest, and motivation. Materials for practice sessions also must be adapted in light of these factors.

The Mechanics of Reading

Reading, like any other industrial activity, may be evaluated in three ways:

- Rate of production
- Quality
- Durability.

A course of training, therefore, must consider rate of reading and degree or quality of understanding, in addition to the lasting effects of the training program.

There are several basic underlying factors in the reading process which might be classified as (a) physical and (b) psychological factors.

Physical Factors

When one reads a line of print, his eyes move in little jumps. A focal point is established (called a *fixation*) followed by a rapid movement to the next focal point. With each fixation, or focal point, one sees a certain number of symbols. Some persons "see" as many as five or more words at one fixation, while others "see" as little as one letter or one syllable. The amount of material seen by an individual is called his *recognition span.* As the eyes travel from fixation to fixation, no material is read because the eye cannot see a symbol while it is in motion. This is not always apparent to the reader because of the short duration of the *inter-fixation* (time lapse between fixations) and the accommodation of the eye and the brain to this blur.

In reading training, one may take advantage of this information and attempt to lengthen the recognition span and, of course, cut down on the number of fixations per line. Increase in recognition span is simply a matter of extension of the utility of peripheral vision. Single fixations last only 25 to 75 microseconds, and all of them could be that short as far as the demands of the retina are concerned. The average college student, however, has a mean fixation length of 240 microseconds. A major principle practiced in many reading courses is to cut down the time element of each fixation, and at the same time to enlarge the accompanying recognition span.

Another principle involves the amount

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In 25 hours—more efficient reading skills for executives

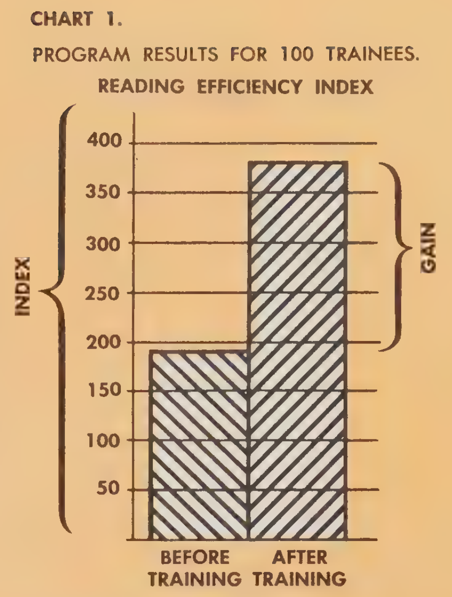


Fig. 1—This bar graph illustrates the increase in the reading efficiency index of the first 100 executives who participated in the experimental phase of the reading improvement training program. (The reading efficiency index encompasses both the rate of reading and the quality of the reader's comprehension of the material.) Analysis of the graph shows an improvement from the initial index of 191 to the final index of 380—a 93.7 per cent increase.

of time consumed between fixations and also that time used in moving from one line to the next. The former is the inter-fixation time, while the latter is termed the *return-sweep time*. If one is able to reduce the number of fixations per line he automatically decreases the number of inter-fixations. This inter-fixation time is about 30 microseconds for the average reader. On the return sweep, if one trains himself to first fixate as far to the right of the beginning of the line of print as his recognition span will permit and to complete the line with a fixation point as far to the left of the end of the line as his recognition span will permit, he may be able to eliminate fixations on over one-third of the line. Consequently, his return-sweep time may be reduced as much as 35 per cent on each line.

Other physical factors which are detrimental to one's reading ability are *vocalization* and *regression*. Vocalization involves any movement of the lips, vocal cords, or any of the vocal apparatus in silent reading. The oral reader reads approximately one-third slower than the silent reader. This is adequately demonstrated at meetings where copies of a report are distributed and one person begins to read it aloud. The persons who are supposedly reading along with him usually find themselves ahead of the reader and are forced to go back and slow down.

Regression is back-tracking over material that has already been read. One of the principal causes of this is lack of confidence of the reader in his ability to understand the material. Exercises and mechanical equipment are available as aids in the elimination of this habit. In reading training programs it is often found that success in measured comprehension is enough to instill more confidence in the reader and, thus, decrease regression.

Psychological Factors

Factors which determine a person's rate of growth in any learning activity, such as improvement in reading, include: (a) the individual differences in ability to learn new and to resist old reading habit patterns, (b) the extent to which one applies himself to the task, and (c) the willingness with which he can accept the idea that he *can* become a better reader. These factors are all related to one's interest in general, and the reading training program in particular, as well as his motivation for improvement.

Most reading programs are designed around the various principles of learning. A scientific approach to the problem has resulted in the formulation of these principles which include consideration of distribution of training, effects of practice, fatigue, relevance of material, association, and interference.

Personality as it affects the reading process has not been investigated as thoroughly as some of the other factors. However, it is known that several personality factors are related to ability in reading. The compulsive person, as an example, has an extremely difficult time "letting go" enough to increase his reading rate. The extremely active or energetic (measured) person has made the greatest improvement in reading programs.

Emotional blocks are a major deterrent to improvement in reading efficiency, as they are to most other areas. Major causes of these blocks may stem from the individual's relationship with the teacher who introduced him to reading, the material with which he was introduced, succeeding teachers, persons of authority, and material, as well as his own feelings of adequacy with specific reading material. Fear of consequence in reading is another blocking factor. This may take the form of fear of reading so fast that comprehension will slip away. These rather normal blocks may be dealt with effectively in a program designed toward the individual approach.

Reading Improvement Program in General Motors

Within the past two years several Divisions of General Motors have become interested in the possibilities of increasing the effectiveness of their managerial, supervisory, and staff personnel through reading improvement training.

General Motors Institute, the central training facility of the General Motors organization, has been engaged in an extensive program of action research with the objective of determining the most practical methods of improving the reading efficiency of members of the various levels of management. As previously mentioned, most of the research in the field of reading has been accomplished with college freshmen. Sound investigation concerning adult reading

CHART 2. PHASES OF THE READING PROGRAM.

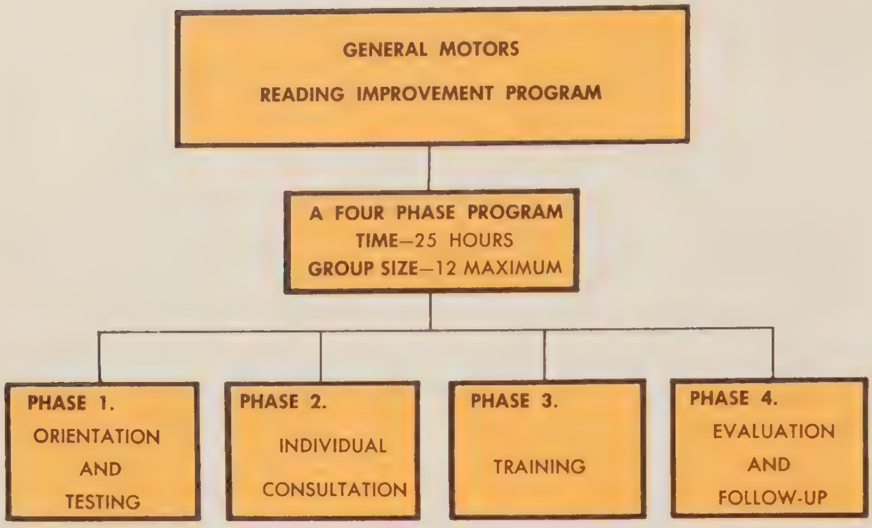


Fig. 2—The reading improvement program, as it now is being offered to engineers and students, is divided into four phases. Altogether, the program consumes about twenty-five hours. The Orientation and Testing Phase assesses the individual's mental alertness, temperament, reading habits, and interests by means of special tests. The Individual Consultation Phase consists of personal, informal interviews between the program participant and the conference leader with the objective of interpreting test scores and analyzing the participant's specific reading problems. The Training Phase—composed of approximately eight sessions, lasting 1½ hr each and held over an eight-week period—presents the principles of efficient reading and periods of supervised reading. The maximum number in a training group is 12. The Evaluation and Follow-up Phase measures the gain in reading ability made, immediately after training, and again some months later.

training has been extremely limited. For a number of years, some thinking had been given to reading training by GM people, but it was not until early 1952 that the action stage was reached. At that time, General Motors Institute, in cooperation with the AC Spark Plug Division, began the development of a training program aimed at increasing the reading efficiency of staff heads, engineers, and superintendents. Other Divisions also had evidenced some interest in a program of this nature.

The investigation and subsequent development of the program was conducted by the author in cooperation with C. A. Brown, chairman of the English and Psychology Department of General Motors Institute, and C. J. Sahrbeck, Jr., administrative chairman, and S. A. Smith, area supervisor, both of the Plant Management Training Department of the Institute.

Preliminary study included investigation of existing academic and industrial programs, review of research material, and consultation with recognized authorities in the field. Extensive findings and recommendations were presented to a committee, composed of Central Office and Divisional personnel, which was organized as an advisory group to the development of this program.

The major recommendation was, in effect, that due to conflicting theories regarding methods of training in reading, this program should be initiated on an experimental or research basis. In this way training could be controlled to the extent that some assessment could be made of the effectiveness of several different methods of training. Other recommendations included a recognition of the need for treating individual reading problems with individual techniques and thorough program evaluation—both subjective and objective—immediately following training, and again some months later. Only in this way could the permanence of the reading gains made in training be demonstrated. Specific program designs were submitted to, and approved by, this advisory committee.

Work then began on the development and assembly of practice reading materials which would be applicable to the interest patterns of industrial executives. These materials included exercises to improve eye movements, reading rate, comprehension, vocabulary, evaluative reading, and speed of comprehension. To supplement this material, it wa planned to make use of current issues o the educational editions of the *Reader' Digest* and the *Atlantic Monthly.* Thes educational editions offer reading im provement practice aids based on article in the regular edition.

Another variety of material was place in the program design by allowing fo personal reading time in the training session. During this time the participan was asked to practice reading with material of his choice. This included novels short stories, or material from one's job

In addition to these, various mechanical equipment generally used in this type of training was made available unde controlled conditions. Equipment included *reading accelerators*, individual and group *tachistoscopes*, and reading films The accelerator is a reading training ai which consists of a shutter which may b set to descend over a printed page at an designated speed. Its primary function i to supply the element of pressure in reading. The tachistoscope is an instrumen which projects an image onto a scree for a predetermined length of time rang ing from 1 sec. to 0.01 sec. Its majo purpose is to develop generalized ski in perception. Reading films embody t tachistoscopic principle in motion pictu form.

The major purpose of developing ne materials was to give the executive som practice in a range of different readin skills to fit the various reading demand in his work, so that he would be helpe to size up quickly his immediate readin situation and to shift readily to his mos suitable skill. Material was included t give some practice in the following area

- Ability to skim
- Getting the main idea
- Reading for detail
- Following directions
- Proofreading
- Evaluative and critical reading
- Speed reading with good compre hension
- Graph and chart reading.

Although one particular engineer ma not be called upon to do all of these type of reading, the majority of them seen relevant. It is fairly obvious that a rang of reading skills is necessary.

Preliminary Steps

When sufficient materials had been developed, a pilot training group composed of Institute instructors was formed. All existing material and equipment were made available to these men in their practice sessions. Many of the rough edges were taken off the program as a result of these training sessions, and additional needed material was developed. An average gain of about sixty per cent in reading ability was noted in this group.

Shortly thereafter, several experimental groups were formed at the AC Spark Plug Division. The AC Spark Plug study was an attempt to determine under rigidly controlled conditions which of several methods of training was most effective in developing the reading ability of the participants. About one-half of the conferees were engineers and the average improvement in reading ability was about one-hundred-ten per cent. It was determined through this study that training could be as effective without machines as with machines, and that the positive results of the training were retained over an extended period.

Further Developments

Other programs, operated on a research basis, have since been conducted at other Divisions of General Motors, with Central Office Staff personnel, and at General Motors Institute with students enrolled in the engineering program. Some changes have been made in the program designed for the engineering students because of school-plant schedules and the specific needs of the student in terms of textbook reading and effective study. Eighty students were trained in the pilot stage of the Institute program, and present plans are to offer the service to 500 volunteer students during this academic year.

Satisfactory results have been obtained with all Divisions to this date. Approximately one-hundred-fifty executives have been trained during the pilot and research phase of the program. Training has been initiated through the facilities of the Plant Management Training Department of the Institute. Close research control has been centrally maintained, and by trying different methods, by varying sessions in number and in length, and by using different types of practice material in different plant situations, better methods of training have evolved. Analysis of the results of the first 100 persons who were trained shows that the average executive reads at 280 words per minute prior to training. This is slightly higher than the average college student. His measured comprehension is 72 per cent which is relatively high, and his *reading efficiency index* is 191. This index takes both rate and comprehension into consideration. As an example of the results of training, these 100 executives increased from the initial reading efficiency index of 191 to the final index of 380 (Fig. 1).

The Revised General Motors Program

On the basis of research findings to date, the program was modified during the summer of 1954. New materials have been added to the course, and a new manual of practice exercises has been developed to better meet the needs of industrial people. More information is being sought regarding the reading interests of specific groups of industrial executives so that the program material may be adapted even more toward meeting the needs of these specific groups. It is planned to continue research and evaluation so that the program will remain at its peak point of efficiency and practicality.

The program as it is now being offered entails the following four phases (Fig. 2):

1. The Orientation and Testing Phase
2. The Individual Consultation Phase
3. The Training Phase
4. The Evaluation and Follow-up Phase.

The total time involved in the program is about twenty-five hours. Training groups are limited to a maximum of 12 persons.

Phase 1—Orientation and Testing

The Orientation and Testing Phase establishes a basis from which to begin training. A complete assessment of various reading factors: mental alertness, temperament, and reading habits and interests is made. Wherever possible a visual screening examination is given in addition to the above tests. An individual's test results are classified as extremely confidential information. They are seen only by the conference leader and the central research staff, and are used only as one aid in developing the individual's reading efficiency.

Phase 2—Individual Consultation

The Individual Consultation Phase is designed as a means of privately interpreting reading ability test scores, examining specific reading problems, and giving information regarding the program to each man. Reading interests are crystallized, motivation is assessed, and an informal, personal relationship is established between the conference leader and the participant. The length of these interviews varies with each individual and ranges from 20 min to 1 hr.

Phase 3—Training

The Training Phase consists of approximately sixteen 1½-hr training sessions over an eight-week period. The time element is flexible and can be adapted to individual plant schedules. Additional sessions can be provided if desired or if the need is evident. The sessions consist of presenting information regarding principles of efficient reading and supervised practice with manuals of specially designed, industrially oriented materials. (Some of these materials have been discussed in a preceding section.) It is believed that one of the keys to success in this training is the self-discipline imposed by small-group training. Outside practice consists merely of the application of new reading principles to everyday reading. Some provision is made for personal consultation during the Training Phase as an additional aid in meeting individual needs. As a result of initial findings, mechanical equipment is used sparingly, or not at all.

Phase 4—Evaluation and Follow-up

In an attempt to maintain the highest possible quality of the program, the Evaluation and Follow-up Phase calls for measurement of reading ability immediately after training, and again some months after training is completed. A subjective evaluation also is elicited from each participant upon the completion of training and is used as a basis for possible revision to the program.

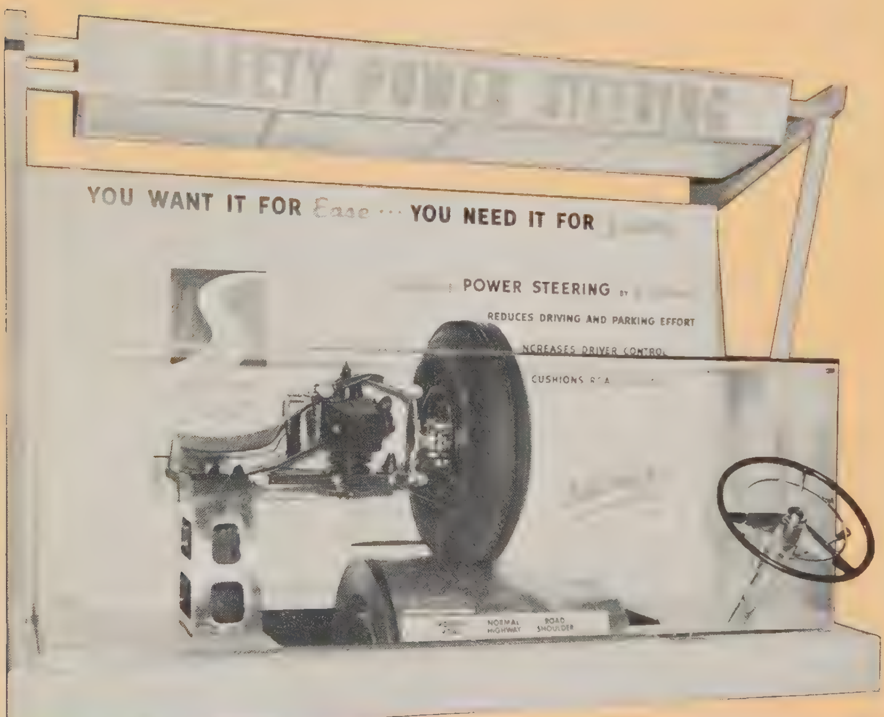
Conclusion

This reading improvement training program has proved effective wherever given in General Motors. Although a relatively new training field in industry, sound, scientific research can make it a continuing aid in the total program of executive development.

Present plans call for further work in this area as a means of increasing efficiency and decreasing the burden of the reading task.

Typical Motorama Exhibits

Typical of the many exhibits in the 1955 GM Motorama show is this display explaining how television is used by the GM Engineering Staff to disclose hitherto hidden facts. A remote eye, mounted on the upper left of the panel, slowly scans visitors to the exhibit and allows them to see themselves projected on the screen at the right. The remote eye is the same type used in car test operations. The use of TV now makes it possible to observe many operations which previously were difficult to determine because of inaccessibility or potential hazard to a human observer. Another advantage is that minute operations can be magnified for instantaneous observation by groups of engineers—in a conference room, for example. Quick changes in testing conditions can be made and observed as a result of making this on-the-spot study.



Another Motorama exhibit incorporates a large aluminum drum to simulate a rough road, a smooth road, and a road shoulder or drop-off. A front-wheel assembly riding on the drum and a steering wheel provide a demonstration of the benefits of power steering on various road surfaces. The drum rotates at a speed comparable to a 30-mph road speed and moves laterally beneath the tire to simulate encountering the different road conditions. By operating a selector switch, the visitor to the exhibit may compare the effects on steering comfort with or without power steering. The reassuring "feel" of the road also is demonstrated.

When disregarding volume manufac ture, designers are free to dream Many 1955 dream car features a of technical interest; some pas "dreams" are now real.

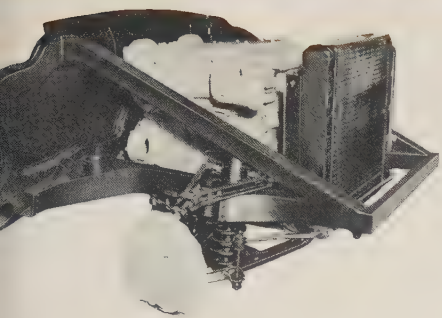
CURRENTLY making its annual showings in five United States cities successively is the General Motors Motorama, a public showing of technological advancements, 1955 products, and other attractions. Among the exhibits which highlight the Motorama are seven new dream cars and even a dream truck. Designed by GM engineers and stylists cooperating with the manufacturing divisions of GM, these vehicles place on display a host of unconventional and novel features. In an engineering and styling sense, the cars are truly *dream cars* for they cannot be purchased by anyone; they were developed as single units without any thought of volume production.

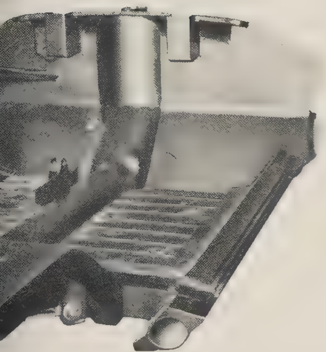
The 1955 dream cars are identified as: the Chevrolet *Biscayne*, the Pontiac *Strato Star*, the Buick *Wildcat III*, the Oldsmobile *Delta*, and the Cadillac *Eldorado Brougham*. In addition, two special cars have been developed by GM's Central Office Styling and Engineering Staffs: the *LaSalle II* sports coupe and the *LaSalle II* sedan. The truck is *L'Universelle*, introduced by GMC Truck and Coach Division.

Dream cars have a widespread appeal to automotive enthusiasts. But these cars also serve as a means whereby the stylist and the product engineer can introduce advanced ideas on an actual vehicle and can test public reaction. They can exercise great freedom in their designs because volume manufacture is not a consideration.

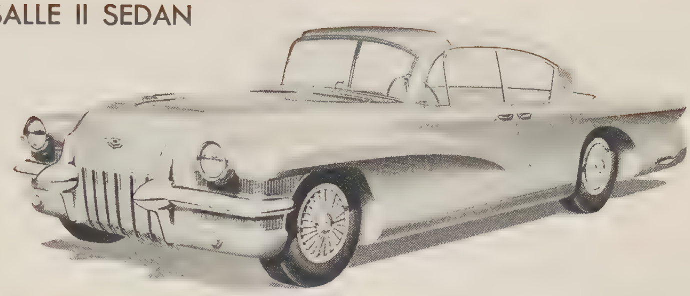
Continued on page 28

Motorama 'Dream Cars' Offer Engineers and Stylists Maximum Design Freedom





LA SALLE II SEDAN



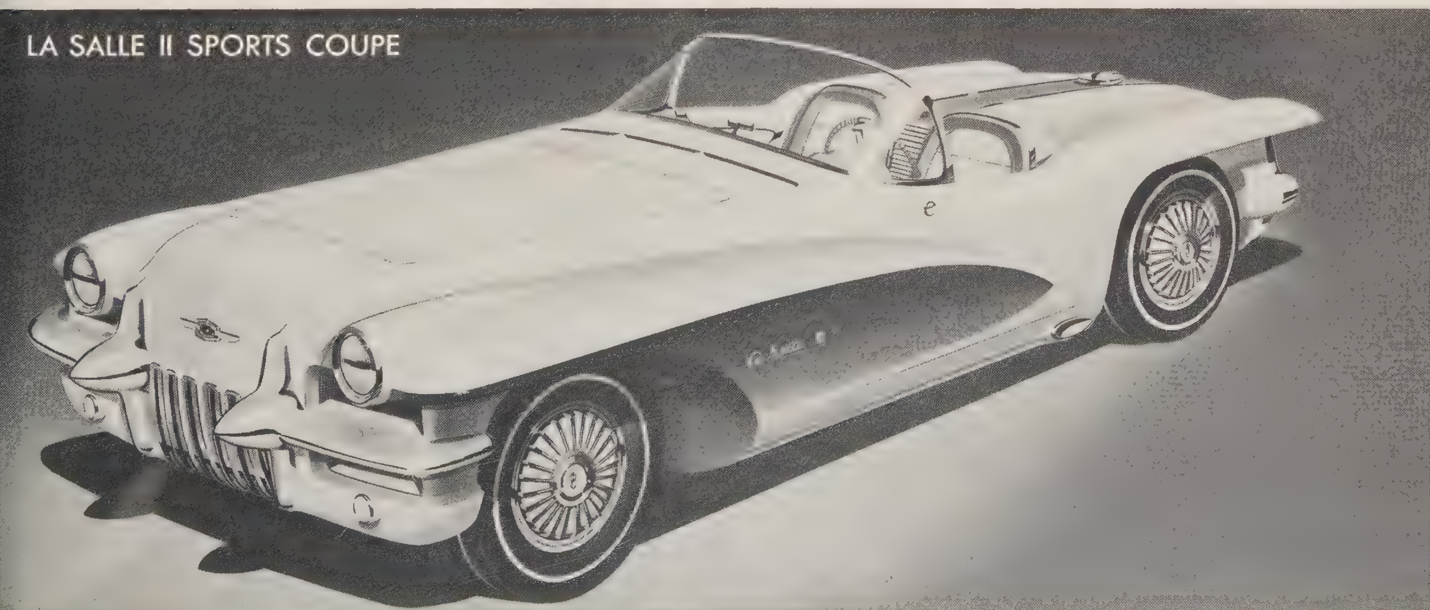
GINEERING DAT

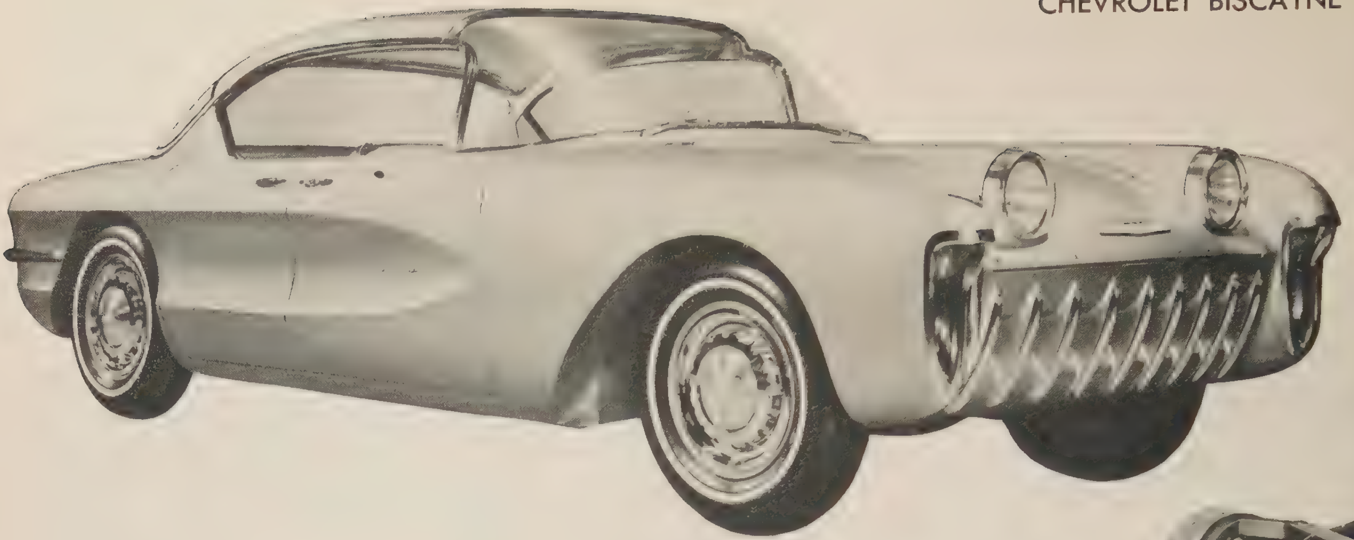
LA SALLE II SEDAN		LA SALLE II SPORTS CAR	
Engine	150 hp V-6	Engine	150 hp V-6
Body Materials	reinforced glass fiber, chrome trim	Body Materials	reinforced glass fiber, chrome trim
Wheelbase	108 in.	Wheelbase	99.9 in.
Overall length	180.2 in.	Overall length	151.7 in.
Overall height	50.8 in.	Overall height	42.8 in.
Overall width	69.5 in.	Overall width	65 in.
Road clearance	6 in.	Road clearance	5.1 in.

The LaSalle II sports coupe and sedan are new niniature-scaled twin dream cars which were amed after the original 1927 car designed for Cadillac by Harley Earl, GM vice president in harge of the Styling Staff. The LaSalle II twins ave the closest ground clearance and smallest limensions of all seven GM dream cars. A drop-loor construction has been achieved by offset-ing the transmission downward with consequent lowering of the driveshaft and driveshaft tunnel. One unusual structural feature of the sedan is the fusing into an integral unit of the floor, body sills, engine supports. and body shell. In addition, the body sill houses both the exhaust pipe and the muffler. The color scheme of the sedan is blue with chrome trim. A visionary innovation on both LaSalle II models is a V-6, overhead-cam type engine designed to develop 150 hp. External-type brakes with fine radial blades are used to dissipate heat generated by the wheels.

The pearlescent white and blue LaSalle II sports coupe is the only two-passenger car exhibited in the group and features a cockpit set well back on the chassis. The suspension is independent, front and rear, with coil springs at each wheel.

LA SALLE II SPORTS COUPE



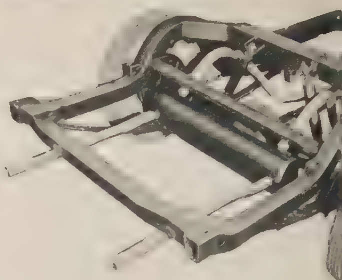


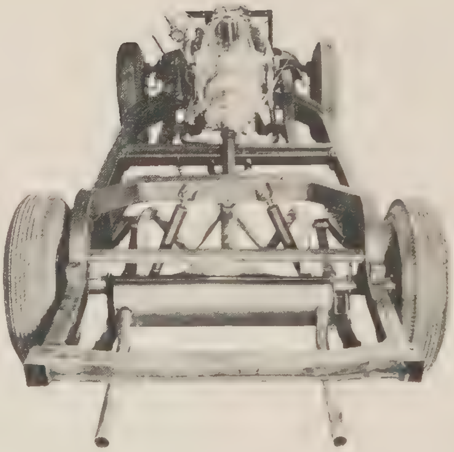
For example, GMC's L'Universelle is a panel truck with many unusual features. Among the engineering departures are a drop-center rear axle, the absence of a driveshaft to the rear, and a front-wheel drive—all to accommodate a floor level 10 in. lower than conventional panel trucks. The engine is placed directly behind the driver and transmits power to the differential through an inverted Hydra-Matic transmission. A drive to the front wheels permits them to move up and down independently of the frame. Torsion-bar springing is used on the front wheels with long leaf springs in the rear. Cooling air for the engine is drawn in from the roof.

In another car—the Pontiac Strato Star—the rear-quarter roof supports are built in the form of airfoil-section cantilever pillars which extend the length of the roof section, joining the windshield header bar. In the roof is a hinged access panel directly above each door. This panel flips up when the door is opened to provide additional head room through the door, and closes automatically to its normal roof position when the door is closed.

A V-6 dream engine and external-type brakes with radial blades for cooling are new features on the LaSalle II sedan and sports coupe models.

Besides the dream vehicles, the GM Motorama features a "Kitchen of Tomorrow" display, scores of engineering and research exhibits, GM's 1955 automobiles and other products, and a specially designed stage. The Motorama,





ENGINEERING DATA

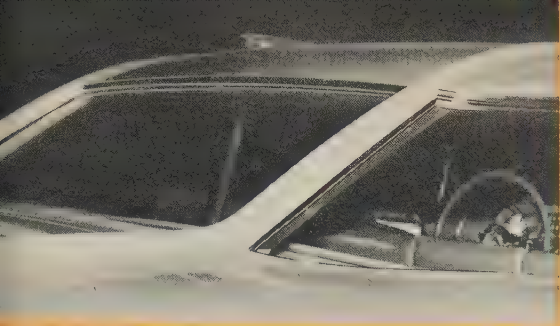
CHEVROLET BISCAYNE	
Engine	215 hp V-8
Body Materials	reinforced glass fiber
Wheelbase	115 in.
Overall length	185.7 in.
Overall height	52.5 in.
Overall width	69.8 in.
Road clearance	6 in.

The Biscayne, a four-door, four-passenger sedan with many engineering innovations as well as nev interior treatment, is the Chevrolet dream car exhibited at the 1955 Motorama. The glass fiber reinforcec plastic body shell evidences the rapid progress being made in plastics technology and permits numerou design features such as the concave sculptured treatment along the body sides. Its high impact resistanc makes feasible the bumper design. The underbody, straddling the side rails, demonstrates the intricat shapes attainable. Four-door construction with no center pillars dramatizes its strength. When closed the doors are latched to the floor and at the belt by a solenoid actuated latching mechanism. The car' low center of gravity is due, in large measure, to its light weight.

Following the trend to expanded visibility, the Biscayne makes use of a novel three-way panorami windshield design. The tinted upper third of this *Astra-Dome* extends above the normal vision line Other exterior design innovations are the hood-mounted headlamps located between the projectil fenders which also house the parking lamps and brake-cooling air scoops; the one-piece grille-bumpe combination; the race-car type air scoops, and the new whitewall tubeless-tire design. The Biscayn is finished in a metallic green color.

A compact interior design has been achieved by dropping the floor to the bottom level of the fram and using the driveshaft tunnel to divide the passenger space into four compartments, each with cockpit-type seat. The front seats pivot for greater passenger convenience. Twin exhaust pipes pas through the driveshaft tunnel, over the axle on either side of the differential housing and into a trans verse cylindrical muffler. Twin outlets fit through framed openings in the lower body panel. The gaso line tank—effectively sealed—is mounted above the rear axle to obtain ground clearance.

An entirely new box-girder frame incorporating five crossmembers underlies the unique body-to frame relationship. Body mounts are rubber cushioned and the floor pan is straddle mounted on the forr fitting side rails. Accurate alignment and reduced vibration have been maintained by attaching bod bolts laterally through spacers and straddling rubber cushions. Another innovation is the solid wal contoured to hold the fitted seat frames, which separates the passenger compartment from the rear c the car to further increase the body shell's structural rigidity.

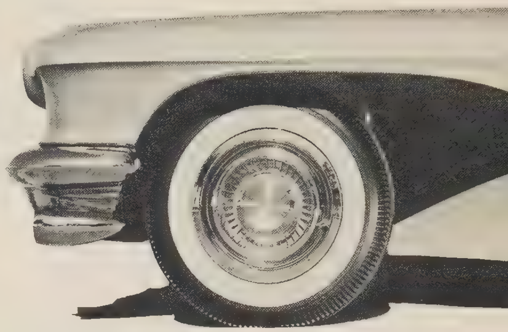


PONTIAC STRATO-STAR

which closes in Boston on May 1, is a dramatization of the forward developments being created in General Motors studios and laboratories.

Some of the innovations displayed on the 1955 dream cars will never be used while others may find their way into future production models. The designs of many cars now available to the public show the effects of experimental cars built two, three, and four years ago. Likewise, dream car features shown today are possibilities in future car and truck design.

Presented on the accompanying pages are photographs of the 1955 GM dream cars.



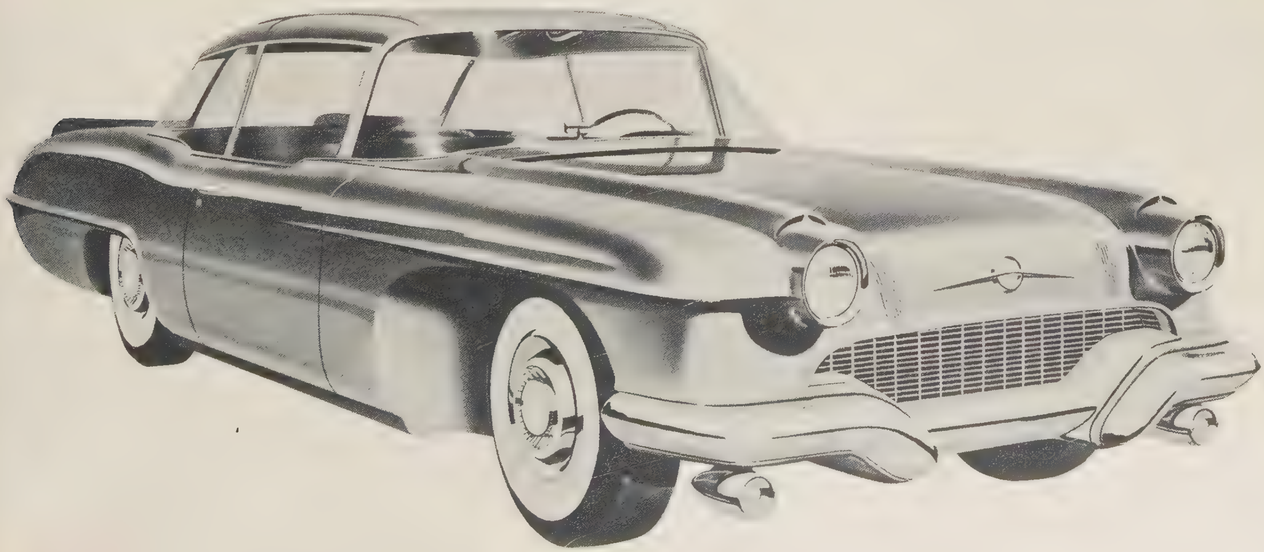
An imaginative design in the hardtop line is this two-door, six-passenger sports coupe developed by Pontiac and named the Strato Star. A novel structural treatment is the use of narrow cantilever pillars which spread from the rear-deck fins across the roof to blend into the front windshield-header bar, creating a rear panoramic window for improved all-around visibility. Another engineering innovation designed for greater passenger convenience is the automatically-controlled access panel over the entrance. The 6-in. panel is actually a hinged portion of the roof section which automatically flips up when the door is opened, for increased head room. By electronic adjustment, the panel automatically returns as part of the roof section when the door is closed.

Design features of the glass fiber body include a concave section at the front fenders and integral construction of the fenders with the low, broad hood. The exterior of the Strato Star is finished in highly metallic silver colored lacquer while the interior is finished in vermillion red and brushed aluminum.

Although the car is only 53.1 in. high, full front and rear seats have been made practicable through the use of a unique drive-line arrangement which permits the floor tunnel to be lowered. For further convenience, the front seat is tri-sectioned—the center section stationary and the two side wings tiltable, for easier entrance to the back seat. The Strato Star's 250 hp V-8 engine is equipped with a four-barrel carburetor.

ENGINEERING DATA

PONTIAC STRATO STAR	
Engine	250 hp V-8
Body Materials	reinforced glass fiber, brushed aluminum
Wheelbase	120 in.
Overall length	202.5 in.
Overall height	53.1 in.
Overall width	75.6 in.
Road clearance	6 in.

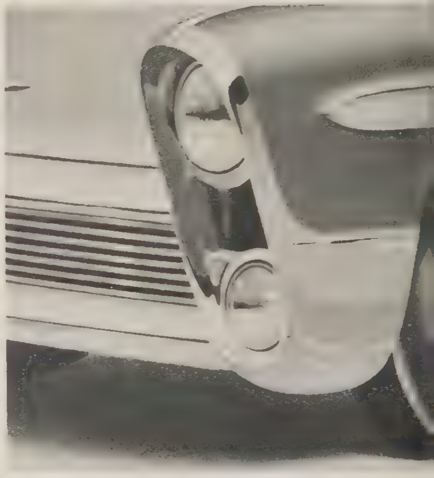


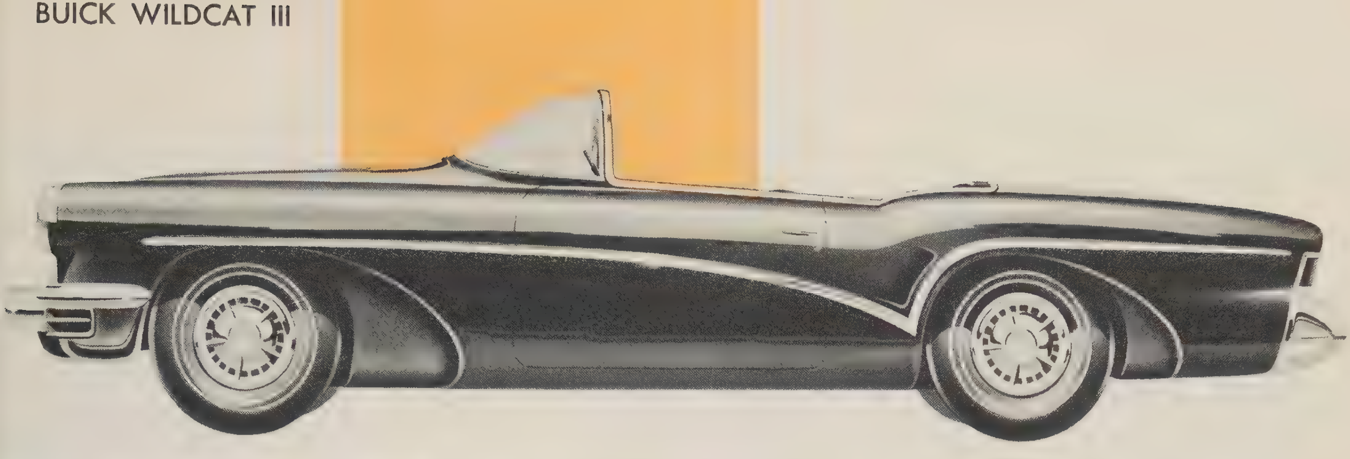
Oldsmobile's Delta—a two-door, four-passenger hardtop coupe—is a dream version of its production model 88. The body of the Delta is of reinforced glass fiber construction but the roof is of brushed aluminum. Coloring on the body is metallic blue and chrome, both inside and out. Among the significant technical innovations in this model are the use of dual-fuel tanks located in the rear fenders and cast aluminum wheels. Other selective design features include individual front swivel seats, oval-contoured front-wheel openings, and wraparound tail lights.

Distinguishing the interior of the Delta is a car-wide, detached horizontal strut that serves as a structural tie bar for the body. Mounted on the strut, which is padded and finished in blue leather, are the speedometer, tachometer, and other controls. A feeling of spaciousness is accomplished by means of a 4-in. clearance between the strut and the car's front interior paneling. Here are located the openings for a clock, radio speaker, heater, and defroster outlets. A tunnel housing, placed between the driver and the front-seat passenger, contains the radio tuning dial, ash tray, and waste container. The rear seat is divided by a storage container which doubles as an arm rest and contains the electric window controls and an ash tray. An unusual hood extends laterally from one front-fender crown to the other with hood edges hidden by the chrome coves on each fender crown. An intake air scoop set between the headlights cools the brake drums. Air for the heating and ventilating system enters flush-type cowl openings. A 250 hp Rocket engine, with compression ratio increased to 10 to 1, powers the Delta.

ENGINEERING DATA

OLDSMOBILE DELTA	
Engine	250 hp Rocket engine
Body Materials	reinforced glass fiber, brushed aluminum
Wheelbase	120 in.
Overall length	201 in.
Overall height	53 in.
Overall width	74 in.
Road clearance	6 in.





Buick's dream model is the Wildcat III—styled in the manner of the family of earlier Buick Wildcat cars. This two-door, four-passenger convertible introduces a new compound-curved windshield design sloping up from the cowl and bending backward in an arc to provide greater wind protection for passengers when the top is down. Another advanced design feature is the frontward-sloping angle of the hood which improves visibility. Air intakes for the passenger compartment are provided by recessing the hood beneath the cowl. Cooling air for the brakes enters two intakes on each side of the front bumper and similarly through intakes in the rear fenders.

An attractive feature for convertible users is the way in which the trunk lid opens from the front, automatically, when the top is lowered to permit storing the top in the trunk compartment.

The Wildcat III is powered by a standard Buick V-8 engine—with 9 to 1 compression ratio—and equipped with four carburetors. The transmission is the standard variable pitch Dynaflow torque converter. Interior equipment includes bucket-type seats which move forward on special struts for easier entrance to the rear seat. New styling features are the vertical windshield pillars, sloping beltline, and teardrop wheel cutouts which partially expose the fender underpart. The full rear-wheel exposure has been carried over from earlier Wildcat models. Colors are sovereign red for the leather-trimmed interior and Kimberly red on the exterior—the latter color named after Jim Kimberly, sports car racer.

ENGINEERING DATA

BUICK WILDCAT III	
Engine	280 hp V-8
Body Materials	reinforced glass fiber
Wheelbase	110 in.
Overall length	190.5 in.
Overall height	51.75 in.
Overall width	72 in.
Road clearance	6 in.

CADILLAC ELDORADO BROUGHAM

The Cadillac Eldorado Brougham—only steel-bodied car among this year's GM dream vehicles—is a four-door, four-passenger sedan finished in an iridescent green color. A low overall height of 54.4 in., the absence of a center door pillar, and dual headlights for efficient road lighting are among the new technical features of this luxury car. A brushed aluminum roof panel extends from the panoramic windshield to the painted sash above the rear window. Outside dimensions have been reduced without sacrificing passenger comfort. Four individual seats are provided and the absence of center door pillars facilitates the easy entrance of passengers. The driver's seat pivots outward for greater convenience. In the dual headlight assembly, the outer lamps provide flat beam city lights while the inner lamps give a penetrating highway light. The Autronic Eye control switches beams automatically.

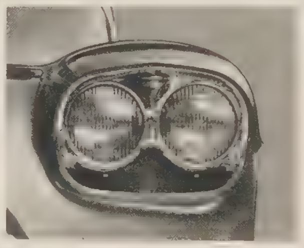
Heating and air conditioning controls are coupled for simple operation and they automatically stabilize interior temperature when once set for operation. The instrument panel is covered with shock absorbent material and all dials and controls are recessed.

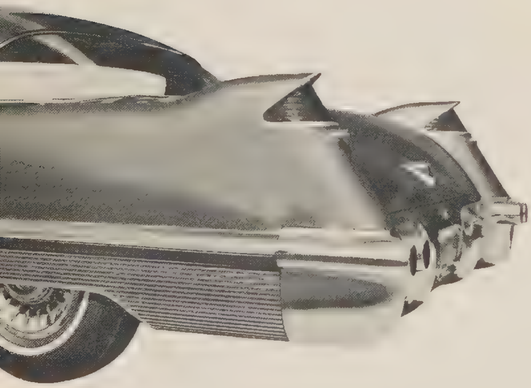
Aircraft-styled fresh air intakes, smooth fender contours, and characteristic tail fins complement the exterior lines of the car.

In addition to the Eldorado Brougham, three specially appointed production cars have been built to complete the Cadillac line of show cars—the *St. Moritz*, a 270-hp Eldorado convertible; the *Westchester*, a Series 60 Special Sedan; and the *Celebrity*, a Coupe de Ville.

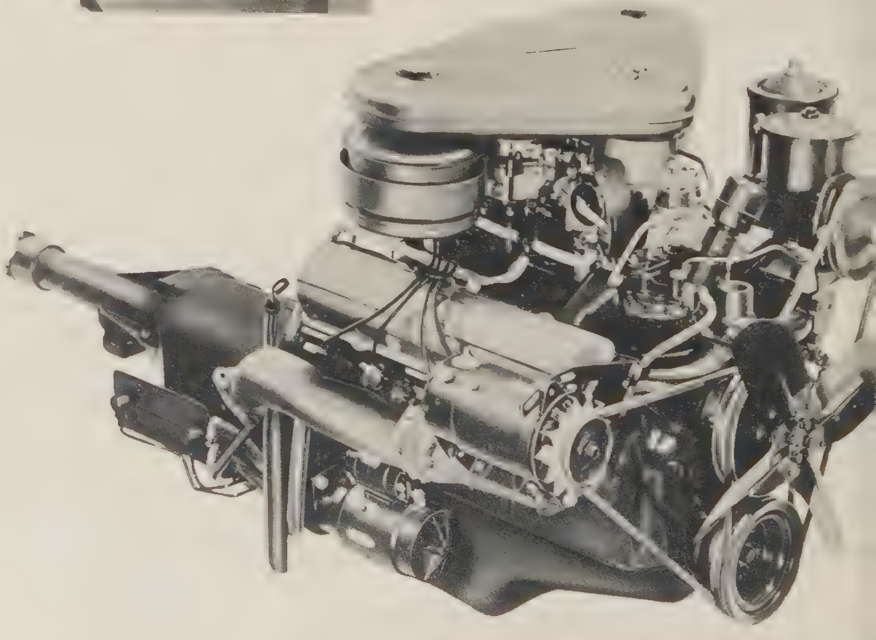
The all-white St. Moritz is outfitted luxuriously in white-leather and ermine-fur trim, with white mouton-fur carpeting. The brilliant-red Celebrity is topped with a matching red leather roof; its interior is fitted in red, silver-threaded cloth, with red leather bolsters trimmed with chrome buttons and silver-finished welts.

The limousine-type Westchester—a study in black leather upholstery, mouton-fur carpeting and Korina gold wood paneling—demonstrates the installation of luxury features such as a television receiver, a telephone, and a tape recorder. These functional conveniences are combined into a built-in unit located in the rear of the front seat.

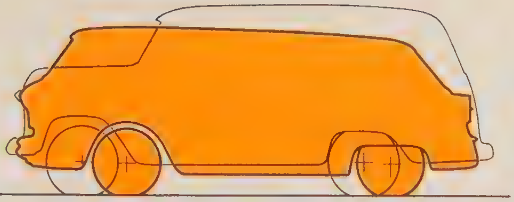


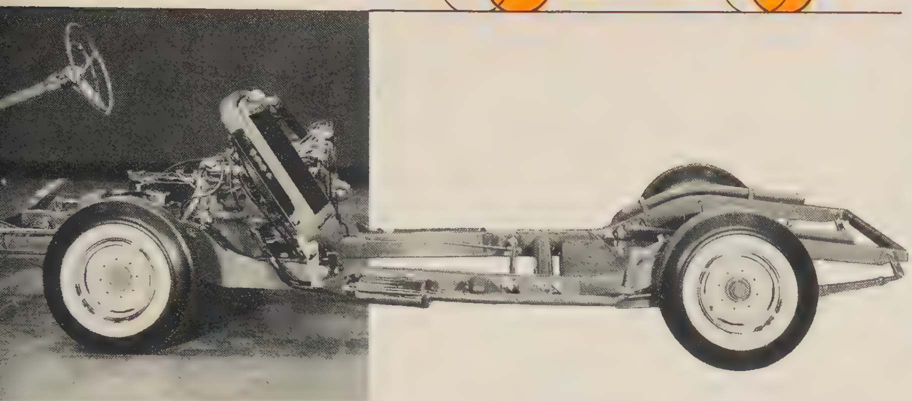


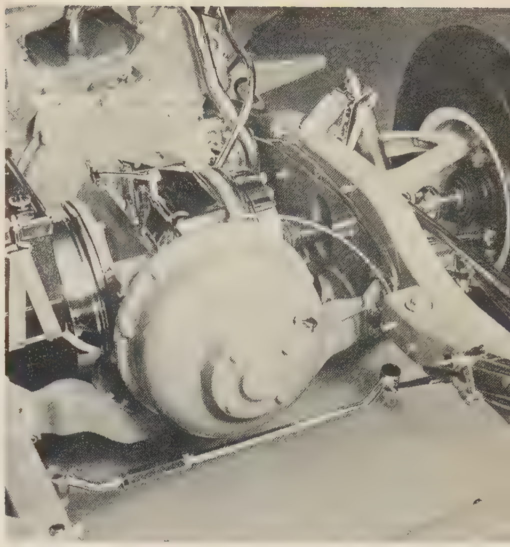
CADILLAC ELDORADO BROUGHAM	
Engine	280 hp V-8
Body Materials	steel body, brushed-aluminum roof panel
Wheelbase	124 in.
Overall length	209.6 in.
Overall height	54.4 in.
Overall width	77.5 in.
Road clearance	6 in.



GMC TRUCK AND COACH L'UNIVERSELLE







A specially designed truck—called L'Universelle—enters the GM dream vehicle group for the first time this year. It is a panel delivery truck built 10 in. lower and 10 in. shorter than conventional models, yet it has a greater capacity. By eliminating the regular driveshaft and adding a drop-center rear axle and front-wheel drive, the floor is lowered to within 13 in. of the ground.

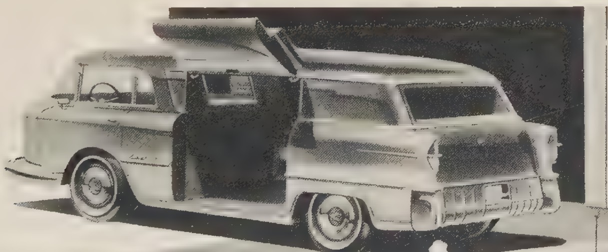
The truck—finished in iridescent copper—is designed along passenger car lines and can be adapted to taxi, bus, station wagon, or sportsman's car use simply by replacing the panels with glass. Modernized technical features include torsion bar springing in front, an inverted Hydra-Matic transmission, front-wheel drive, and a reinforced glass fiber plastic body.

The engine is in a novel location behind the driver, permitting improved visibility. Panels behind the driver's seat and the load wall provide access to maintenance of mechanical equipment. Cooling air enters through a roof intake and is fed through two ducts into the radiator core.

The front-wheel drive insures excellent traction effort—under a 1,000-lb load, 54 per cent of the gross vehicle weight is on the front wheels. This feature also gives greater maneuverability and improved control on turns by pulling the truck body around corners instead of pushing it. L'Universelle offers three loading doors; besides the rear opening, there are two side doors which open to a 46-in. high and 48-in. wide opening. These doors fold upward on a four-bar hinge, extending 20 in. away from the body to afford an unobstructed opening.

L'Universelle typifies the teamwork approach used in designing the dream models—Harley Earl, vice president in charge of the Styling Staff, conceived the design; C. A. Chayne, vice president in charge of Engineering, drew up the engineering plan; the chassis was built by GMC Truck and Coach Division's engineering staff; and the truck was completed by the Styling Staff.

GMC TRUCK AND COACH L'UNIVERSELLE	
Engine	180 hp V-8
Body Materials	reinforced glass fiber
Wheelbase	107 in.
Overall length	188 in.
Overall height	67.6 in.
Overall width	67 in. interior load compartment
Road clearance	13 in.



Patents May Be Used by the Engineer as an Excellent Source of Technical Information

The engineer uses as sources of information numerous treatises, texts, and publications. One of the valuable sources of information often overlooked, however, is the patents issued by the United States Patent Office. These patents provide a review of over a century and a half of engineering progress in all fields of endeavor. There are well over two and one-half million in number, all of which are carefully classified according to subject matter claimed. They are readily available for searching in a public search room maintained by the United States Patent Office in the Commerce Building in Washington, D. C. The search room is staffed with Patent Office employes whose duties include assisting the public in searching these patents. If patents are desired for further examination and use, copies may be obtained from the Patent Office for 25 cents each. These patent copies are exact duplicates of the original except that the cover page, which contains the patent grant, is not reproduced.

From the above it can be appreciated that the engineer has at his disposal a vast fund of readily accessible information which may afford him certain benefits and advantages not obtainable elsewhere. It is appropriate to examine here one of the ways in which the engineer might put these patents to work for him.

An "Art Collection" Is Obtained

The engineer often finds that he is faced with unfamiliar problems not previously encountered. They may concern the development or improvement of a product or process about which he knows little or nothing. As a result, he does not know where to begin the development or where to look for pertinent background material. One way that he might start is to make a study of classified patents in the Patent Office. To do this he can obtain what is known as a patent *art collection*, that is, the most pertinent patents relating to the product or process. A collection of patents can be made in a short time (either by a professional searcher or by the engineer himself) which provide him with a wealth of information relating to the product or process in which he is interested. If the engineer works for a corporation, it no doubt will have a patent section which will obtain the collection for him.

In order to illustrate the manner in which the engineer might employ these patented art collections, assume that he is faced with the development of a variable speed fan drive which is to be responsive to engine temperature in order to provide uniform cooling for an internal combustion engine at various engine speeds and ambient temperatures. He might first request a preliminary patent collection on this type of drive. Upon obtaining the collection he no doubt would be very surprised to find that there are huge numbers of patents on different types of thermally responsive variable fan drives. These patents would include friction-type clutches in which the sliding frictional forces between the clutch plates of the driving and driven members are varied with engine temperature. They would include hydraulic couplings which fill and empty to vary slip between driving and driven members in response to engine temperature, eddy-current clutches whose excitation is varied according to engine temperature, and so on. The engineer might then decide that an eddy-current coupling would be the most desirable for his needs and order a further collection of patents on only that type. Now he can accurately determine just how such eddy-current variable speed drives are constructed and work, as well as the problems which they were developed to overcome. A careful analysis of the patents will teach him which features are most desirable and may lead him to combine them in his own drive. He will no doubt observe defects to be avoided and, what is even more important, will be encouraged to creative thinking which is likely to result in a superior drive with novel features.

There is no intention to imply that the beginning suggested above is always the best or the only way of starting an engineering development. It is one way of approaching the problem, however, particularly if the engineer is at a loss as to where to begin. It is said of Thomas Edison that when working in a new field he almost always read all the previous patents in the field in order to benefit from the knowledge of others in that field and provide himself with a proper background. The general feeling of patent attorneys is that the study of prior patents, in many instances, can be useful to engineers because these patents are often filled with good ideas which for reasons such as lack of promotion or inadequate means of production have not been commercially successful.

Product Changes Required by Infringed Patents Can Be Avoided

Another benefit obtained in the study of patents prior to undertaking a new development is that the engineer, through the aid of a competent patent attorney, may determine the scope of coverage of unexpired patents in the field and engineer his new development to avoid the areas "staked out" and protected by these patents. This has the advantage of requiring a considerable amount of creative thinking on his part. It may also avoid later changes in the product, changes in tooling, or changes in production schedules, which might be required if a product is developed without a proper interpretation of these patents. It

By JEAN L. CARPENTER
Patent Section
Central Office Staff

New products or processes sometimes start with a patent collection

should be emphasized, however, that interpreting the scope of an unexpired patent is a highly technical matter requiring specialized knowledge and training and should not be undertaken without the assistance of patent counsel.

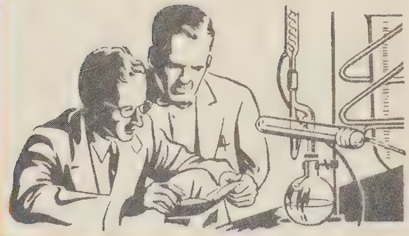
By their very nature and because of the requirement of certain of the patent laws, patents often provide more accurate, complete, and up-to-date information on new developments than do most textbooks or technical publications. In fact, in certain cases, such as electronic computing machines, one of the very few places an engineer can obtain any detailed, accurate information is in the patents taken out on such machines.

Summary

The engineer has available as useful tools a wealth of information in the form of prior classified patents from which he may make "art collections." These collections may be used as stepping stones to the development of new and better products or processes. The collections are also useful for supplying the engineer with background material in an unfamiliar field. With the aid of a competent patent attorney these collections are additionally valuable for avoiding the pitfalls of developing a commercial product or process which may infringe patented inventions of others.

***Biographies of inventors marked with an asterisk in this section have been published in Volume 2, Number 1 of the GENERAL MOTORS ENGINEERING JOURNAL.**

Notes About Inventions and Inventors



Contributed by Patent Section Central Office Staff

THE following is a listing and descriptions of some of the patents granted to General Motors prior to November 30, 1954. The brief patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each patent.

Patents Granted

• **Clayton B. Leach,** *Pontiac Motor Division, Pontiac, Michigan, for a Valve Rocker Mounting, No. 2,669,981, issued February 23.* This invention relates to individually mounted valve operating rockers and means for conducting oil thereto by a stud extending through the rocker from the cylinder head and supporting the rocker bearing at its upper end.

Mr. Leach is assistant motor engineer in Pontiac Motor's Engineering Department. His 20-year career with General Motors has been spent at this Division. He was a student engineer from 1935 to 1937, then promoted to draftsman. In 1941 Mr. Leach was promoted to designer, to senior project engineer on engines in 1947, to motor development engineer in 1950, and to his present position, assistant motor engineer, in 1954. Mr. Leach holds the A.B degree (1934) from Park College in Missouri, and graduated from General Motors Institute in product engineering in 1937. He has been a member of the Society of Automotive Engineers since 1939.

• **John R. Gretzinger,** *Buick-Oldsmobile-Pontiac Assembly Division, Kansas City, Kansas, for a Filter, No. 2,685,371, issued August 3.* This patent discloses a continuous by-pass or bleed hole for an oil filter to warm cold oil in the filter, a plate fitting in a chamber and having a small clearance around the entire perimeter to prevent the passage of particles large enough to clog the bleed hole.

• **John R. Gretzinger,** *Buick-Oldsmobile-Pontiac Assembly Division, Kansas City, Kansas, for an Oil Filter, No. 2,689,652, issued September 21.* This invention relates to a filter element for removing sludge from oil in which an endless strip of filter material is folded into spaced pleats of substantially involute form and surrounds a perforated oil outlet tube.

Mr. Gretzinger serves as chief engineer at the Kansas City plant of the B.O.P. Assembly Division. Mr. Gretzinger began his General Motors career in 1934 as a junior engineer with the AC Spark Plug Division at Flint, Michigan. At AC he advanced to the position of development engineer, working principally on oil-filter designs. His work with oil filters led to these two patents, applied for when Mr. Gretzinger was connected with AC Spark Plug. In 1951 he transferred to the B.O.P. Assembly Division as an administrative engineer at the Kansas City plant. During the same year he was promoted to assistant chief engineer and finally chief engineer. In 1934 Purdue University awarded him the B.S. degree in mechanical engineering.

• **Robert W. Chester, Robert T. Harnett, Darrell E. Royer, and John H. Smith,** *Aeroproducts Operations of Allison Division, Dayton, Ohio, for a Solenoid Actuated Switch, No. 2,686,855, issued August 17.* This patent relates to a solenoid actuated switch for effecting intermittent energization of a plurality of heating elements for de-icing propeller blades.

Mr. Royer serves as a designer in Aeroproducts' Engineering Department. He started with that Department in 1946 as a senior detailer. In 1949 he was made junior designer and in 1951 was promoted to his current position. His design work has been concerned chiefly with the development of governors and valves for propellers. Mr. Royer studied at Sinclair College in Dayton and University

of Dayton. Previous to employment with General Motors, he was engaged in tool design at Lear, Inc. Mr. Royer served in the Navy from 1944 to 1946.

Mr. Smith is senior project engineer in Aeroproducts' Engineering Department. He joined the Division in 1943 as a detailer. Regular promotions led to his position as supervisor of the Drafting Department in 1950 and, three years later, he was promoted to his present position. Among Mr. Smith's engineering assignments have been design and developmental work on hydraulic starters, air generators, air-driven pumps, propeller test equipment, and sundry automotive projects. In 1949 he earned the B.S.M.E. degree from University of Michigan. Mr. Smith served in the Air Force for three years, specializing in radar work.

Mr. Chester is no longer with the Division.

Mr. Harnett is no longer with the Division.

• **Samuel R. Callaway and Fred J. Webbere,** *Electro-Motive Division, LaGrange, Illinois and Research Laboratories Division, Detroit, Michigan, respectively, for a High Temperature Creep Resistant Alloy, No. 2,688,536, issued September 7.* This patent relates to a nickel-base alloy containing a minimum of strategic materials which is adapted for parts such as, for example, buckets or blades for gas turbines requiring high temperature properties including high stress rupture life, ductility, and resistance to thermal shock and oxidization.

• **Fred J. Webbere,** *Research Laboratories Division, Detroit, Michigan, for Wear Resistant Cast Iron for Cylinder Liners and the Like, No. 2,691,576, issued October 12.* This patent pertains to a cast iron characterized by outstanding wear resistance and anti-score properties resulting from the presence of nickel, titanium, and phosphorus in the composition. The cast iron is particularly useful for cylinder liners of internal combustion engines.

Mr. Callaway, until recently a metallurgical engineer with the Manufacturing Staff's Production Engineering Section, is now chief metallurgist for Electro-Motive Division. He was originally employed as a junior metallurgist by the Research Laboratories Division in 1940 and, after several intermediary promotions, was made supervisor of heat treating in that Division's Processing Department. Work for this patent was completed while Mr. Callaway was connected with the

Research Laboratories. In 1953 he was transferred to the Manufacturing Staff. University of Minnesota awarded Mr. Callaway the B.S. degree in metallurgical engineering in 1940. He is a member of the honorary society Tau Beta Pi, and the A.S.M. and S.A.E.

Mr. Webbere serves as supervisor of alloy-development melting in the Metallurgy Department of the Research Laboratories. He was appointed to his present post in 1954, after advancing through the positions of research metallurgist and senior engineer. He began in this Department in 1941 as junior engineer following his graduation from University of Wisconsin with the degree of Bachelor of Science. He has been elected to Tau Beta Pi and he is a member of the American Society for Metals and the American Foundrymens Society.

• **Roland R. Bishop and Maurice Olley,** *Vauxhall Motors, Limited, Luton, England, and Chevrolet Motor Division, Detroit, Michigan, respectively, for Leaf Springs for Vehicles, No. 2,690,334, issued September 28.* This invention relates to leaf spring constructions wherein stop means are provided to limit flexing of the springs induced by wheel torque.

Mr. Bishop is a commercial vehicle engineer for Vauxhall Motors. Mr. Bishop's first position with Vauxhall was as designer in 1931. He was promoted to assistant experimental engineer in 1933 and four years later was made commercial vehicle experimental engineer. In 1940 he was promoted to his current position in charge of Bedford truck engineering. During the last war, he was responsible for engineering development of the Bedford wheeled and semi-track vehicles used by the British Army. Mr. Bishop is a member of the Institution of Mechanical Engineers.

Mr. Olley is director of the Research and Development Section, Chevrolet Motor. His education and early engineering work were in England where he became personal designer for Sir Henry Royce. Later, he became chief engineer for Rolls Royce in America. From 1930 to 1937 he was successively special projects engineer for Cadillac Motor Division and for the General Motors Corporation. From 1945 until joining Chevrolet in 1952, he was technical consultant to Vauxhall Motors, England, where his work with automotive suspensions resulted in this patent. His GM engineering work has resulted in 19 U. S. and seven Canadian patents.

• **Robert H. Duckwall,** *Allison Division, Indianapolis, Indiana, for a Thermocouple, No. 2,690,462, issued September 28.* The invention provides a rugged thermocouple having a tubular outer electrode with a radial terminal and a coaxial inner electrode received therein.

Mr. Duckwall is senior project engineer in the Jet Turbine Components Department at Allison. He embarked on his General Motors career in September 1937 as a junior equipment engineer in Frigidaire Division's Standards Laboratory. He became a project engineer in 1944 and three years later transferred to Allison where he was promoted to his present position in late 1954. His current work involves, primarily, the electrical wiring of the turbo-jet (J71) engine. Purdue University awarded Mr. Duckwall the B.S. degree in electrical engineering in 1933.

• **Glen R. Betz,** *Moraine Products Division, Dayton, Ohio, for a Load Hook, No. 2,690,926, issued October 5.* This patent relates to a stock lifting hook having an arrangement to adjust the center of gravity of the loaded hook to maintain balance.

Mr. Betz is a process engineer at Moraine Products. He was a co-op student at General Motors Institute when he joined the Division's Personnel Department in 1940. From 1943 to 1946 Mr. Betz served in the Navy as an engineering officer. On his return to Moraine Products in April 1946 he was assigned to the Process Department as a junior engineer. In 1950 he was promoted to his present position. Mr. Betz was graduated in early 1944 from G.M.I. in industrial engineering and earned the B.S. degree from Worcester Polytechnic Institute in late 1944.

• **Charles D. Graham,** *Frigidaire Division, Dayton, Ohio, for a Self-contained Air Con-*

ditioning Unit, No. 2,690,654, issued October 5. This patent relates to a compact air conditioning unit with interchangeable outer panels making it possible to connect the return air duct to either the back, front, or top of the unit.

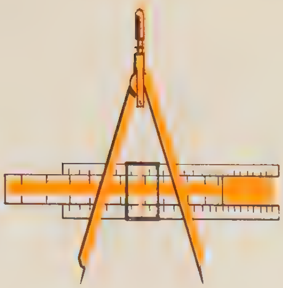
Mr. Graham is supervisor of the major product line in the Air Conditioning Engineering Department at Frigidaire—concentrating on residential air conditioning. He started with the Division in 1933 as a senior engineer in the Research Engineering Department. His past projects relating to window air conditioners and self-contained air conditioners have led to eight granted patents. Mr. Graham holds the B.S. degree in mechanical engineering from University of Kentucky (1923). In addition, he is a member of the Technical Advisory Committee on Air Cleaning, American Society of Heating and Air Conditioning Engineers.

• **Joseph R. Pichler***, *Frigidaire Division, Dayton, Ohio, for an Open-Top Display Refrigerating Apparatus, No. 2,690,650, issued October 5.* This patent covers an open-top self-serve refrigerated display case with side-by-side storage compartments formed by spaced hollow flues which improve air circulation because of baffles in a cold air by-pass beneath the compartments which scoop air from the by-pass up into the flues.

• **Wilford H. Teeter and John J. Preotle,** *Frigidaire Division, Dayton, Ohio, for a Noise Eliminator for Refrigerating Apparatus, No. 2,690,652, issued October 5.* This patent relates to a surge chamber assembly which may be installed between a standard refrigerant compressor and the usual shut-off valve in installations where the noise of the surging refrigerant is objectionable.

• **Wilford H. Teeter,** *Frigidaire Division, Dayton, Ohio, for an Open-Top Display Refrigerating Apparatus, No. 2,693,089, issued November 2.* This patent pertains to an open-top self-serve refrigerated packaged ice cream storage display case. A novel arrangement of baffles within the case uniformly distributes air below zero throughout the interior thereof.

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.



Mr. Teeter is supervisor of the major product line in Frigidaire's Engineering Department. Mr. Teeter's 35 years with General Motors have included experience with the Delco-Light Company (later made Delco Appliance Division) and the Research Laboratories and Frigidaire Divisions. He transferred to Frigidaire in 1930 and was promoted to his current position in 1937. Mr. Teeter's past research with carburetors, household compressors, air conditioners, and reciprocating and rotary compressors has led to 52 granted patents.

Mr. Preotle is senior project engineer in the Commercial Engineering Department of Frigidaire. In 1935 Mr. Preotle joined this Division as a student trainee, directly after earning the Bachelor of Mechanical Engineering degree from The Ohio State University. In his 29 years with Frigidaire, Mr. Preotle has worked on the design and production of both military products—the recoilless gun, a propeller metal cuff for the B-29, and the 50-caliber gun barrel—and civilian products—low-temperature cabinets and ice cream and food freezer cabinets. He is a member of the Ohio Society of Professional Engineers.

• **Harold E. Fox and William E. Rice,** *GMC Truck and Coach Division, Pontiac, Michigan, for a Fluid Suspension System for Vehicles, No. 2,691,420, issued October 12.* This patent concerns an air suspension system particularly adapted for use on motor coaches having tandem rear axles in which a leveling valve associated with the suspension operates to maintain the coach body at a constant level, irrespective of the load.

Mr. Fox is development engineer at GMC Truck and Coach. He attended Carnegie Institute of Technology for both undergraduate and post graduate work. Mr. Fox began his career with General Motors in 1934 as a project engineer in the Engineering Department of GMC Truck and Coach. In 1943 he advanced to senior engineer; in 1945 he was promoted to section head engineer; and attained his present position, development engineer, in 1947. His past projects in coach structural design, air conditioning, air suspension systems, and transmission development have resulted in six patents and 10 published papers in the fields of electrical, aeronautical, and automotive components. Mr. Fox is a member of Alpha Tau honorary society, the Society for Experimental Stress Analysis, the Society of Automotive Engineers, and the S.A.E. Committee on Ride Research.

Mr. Rice is no longer with the Division.

• **Charles H. Frick,** *Detroit Diesel Engine Division, Detroit, Michigan, for a Governor with Self-Fluid Pressure Override Means, No. 2,691,382, issued October 12.* This patent covers a speed governor actuated valve for controlling a fluid transmission lock-up or direct drive clutch so as to delay the clutch engagement during engine acceleration and its disengagement during engine deceleration.

Mr. Frick is senior project engineer in Detroit Diesel Engine's Engineering Department. He first joined the Division in 1942 as a student engineer in the Engineering Laboratory. Since then, he has been promoted to project engineer (1946) and to his present position, senior project engineer (1952). In this capacity, Mr. Frick is in charge of the design and development of governors and controls for all engines manufactured at the Division. Mr. Frick's work in this field has resulted in one granted and seven pending patents. He was granted the B.S. degree from Iowa State College in 1934.

• **C. W. Lincoln* and Philip B. Zeigler,** *Saginaw Steering Gear Division, Saginaw, Michigan, for a Follow-up Mechanism, No. 2,691,308, issued October 12.* This patent relates to a mechanical follow-up device adapted for use as a power steering servo utilizing a pair of oppositely rotating clutches corresponding to the two directions of turn, whose driven components power the steering shaft. Manual turning of the steering shaft causes relative axial movement of a control element associated with the shaft which engages one or the other of the clutches.

• **C. W. Lincoln*, Philip B. Zeigler, and Henry D. Spiekerman,** *Saginaw Steering Gear Division, Saginaw, Michigan, for a*

Direction Signal Switch, No. 2,691,704, issued October 12. This patent relates to a manually settable, self-cancelling direction signal switch mechanism having overriding means for preventing jamming of the steering wheel should a foreign article become lodged in the mechanism.

• **Philip B. Zeigler and Joseph J. Verbrugge,** *Saginaw Steering Gear Division, Saginaw, Michigan, for a Window Wiper and Defroster Unit, No. 2,693,612, issued November 9.* This patent covers a mounting arrangement for a unit defroster and windshield wiper structure especially applicable for use on the rear window of an automobile.

• **Philip B. Zeigler and Arthur B. Winchell,** *Saginaw Steering Gear Division, Saginaw, Michigan, for a Window Wiper and Defroster Unit, No. 2,693,613, issued November 9.* This patent pertains to an electrical driving and power unit for a unit defroster and windshield wiper structure especially applicable for use on the rear window of an automobile.

Mr. Zeigler serves as assistant chief engineer in the Product Engineering Department of Saginaw Steering Gear. After earning the B.S. degree in engineering from Purdue University in 1941, he was employed by General Motors in June of the same year as a time study engineer at this Division. Mr. Zeigler's research with power steering and signal switches has led to 11 granted patents. He is chairman of the program committee of the Mid-Michigan Section of the Society of Automotive Engineers.

Mr. Verbrugge is project engineer in the Product Engineering Department at Saginaw Steering Gear. He was originally employed by General Motors in 1936 as a drill press operator at this Division. Mr. Verbrugge graduated from General Motors Institute in 1941. He is currently engaged with forward development in power steering. Mr. Verbrugge's technical affiliations include membership in the Society of Automotive Engineers.

Mr. Spiekerman is no longer with the Division.

Mr. Winchell is no longer with the Division.

• **George W. Onksen*,** *Guide Lamp Division, Anderson, Indiana, for an Apparatus for Making Dies for Reflector Signals, No. 2,691,905, issued October 19.* This patent covers an improved apparatus for making dies of the type used in manufacturing glass or plastic reflex reflectors.

• **Arthur J. Schutt, Willard O. Emmons, and Charles J. O'Brien*,** *Harrison Radiator Division, Lockport, New York, for a Heat Exchange Device, No. 2,691,991, issued October 19.* This patent pertains to an improvement in heat exchange devices, particularly automobile radiators. The construction is especially distinguished by the provision of turbulence inducing elements which speed up heat transfer.

Mr. Schutt serves as assistant chief engineer, in charge of the Research Section of the Engineering Department at Harrison Radiator. Employed as an engine designer in the Product Study Department, Central Office Engineering Staff, in 1929, he transferred to Harrison Radiator in 1931 as an experimental engineer. He was promoted to assistant chief product engineer in 1936 and to his present position in 1948. This is the eighth patent granted as a result of Mr. Schutt's work in the fields of heat transfer and temperature controls. Mr. Schutt is a member of the S.A.E.

Mr. Emmons is assistant chief research engineer in the Engineering Department of Harrison Radiator. Employed by this Division in 1928 as a junior engineer, he has been promoted through the positions of development engineer (1931), project engineer (1937), and senior research engineer (1941) to his present position (1948). Mr. Emmons earned the B.S. degree in mechanical engineering in 1927 from Clarkson College of Technology, Potsdam, New York. His early work in connection with automotive radiators and heat exchangers has resulted in nine granted patents. His technical affiliations include membership in the S.A.E.

• **Edgar D. Springer,** *Guide Lamp Division, Anderson, Indiana, for a Prismoidal Rear View Mirror, No. 2,691,919, issued October 19.* The patent relates to an anti-glare rear view mirror of the prismoidal type in which reflecting plates are retained in a mounting bracket by a pair of spaced resilient supporting arms defining a reflecting sub-assembly which is mounted within a housing for forward and rearward pivotal action about its top edge.

Mr. Springer is general foreman in the model shop of Guide Lamp. He joined the Division 24 years ago as a model maker in the model shop and through a series of promotions was made assistant foreman and, later, general foreman—his present position. Mr. Springer studied engineering from the International Correspondence School. One granted and two pending patents covering automotive lighting have resulted from his work.

• **Robert R. Candor,** *Patent Section, Dayton, Ohio, for a Combined Agitator and Flexible Diaphragm for Washing Machine, No. 2,692,494, issued October 26.* This patent relates to a flexible bag washing machine in which the bag is supported and oscillated in a fluted shape for the washing operation and in which a partial vacuum is produced to collapse the bag and extract the clothes.

Mr. Candor is assistant patent counsel in the Dayton Office of the Patent Section, located at Frigidaire Division. Employed in 1925 as a patent searcher in the Washington, D. C. office of the Patent Section, he became patent attorney at Frigidaire in 1928 and was promoted to supervisor of the Frigidaire Patent Section in 1952. Mr. Candor received the B.S. degree in 1912 from Wooster University. He is a member of the bar in Washington, D. C. and Ohio and belongs to the Dayton Patent Bar Association. Mr. Candor's work has resulted in a total of 44 patents in the field of refrigerator and domestic appliances.

• **Carl Habel,** *Packard Electric Division, Warren, Ohio, for an Assembling Machine, No. 2,692,424, issued October 26.* This patent covers a machine for automatically assembling a lamp socket and parts associated therewith. The socket and parts are contained in hoppers from which they are fed to a step-by-step rotary conveyor and assembled in the socket automatically as the socket is moved by the conveyor to different work stations.

Mr. Habel is master mechanic at Packard Electric. In 1930, after earning the Bachelor of Industrial Engineering degree from The Ohio State University, Mr. Habel joined Delco-Remy Division as a student engineer. Six years later, he

transferred to Packard Electric as chief process engineer and was promoted to master mechanic in 1946. This patent, covering an automatic assembly machine, is the first granted as a result of Mr. Habel's work.

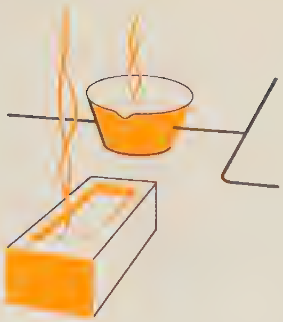
• **Joseph F. Bertsch and George W. Jackson,** *Delco Products Division, Dayton, Ohio, for a Power Transmitting Device with Resilient Shock Absorbing Means, No. 2,692,661, issued October 26.* This patent covers a self-centering power transmitting device incorporating a shock absorber to snub and absorb heavy shocks and prevent direct transmission of the shock to the power transmitting device.

Mr. Jackson is section engineer—research and development—in the Engineering Department of Delco Products. His initial General Motors experience was with the Inland Manufacturing Division from 1937 to 1940. Mr. Jackson joined Delco Products in 1944 as a design engineer and was promoted to his present position in 1947. He earned the B.S.M.E. degree from Purdue University in 1937. Mr. Jackson's work with optical machinery and electro-mechanical actuators and controls has resulted in several granted patents and one published paper on actuator design. His technical affiliations include membership in the Society of Automotive Engineers.

Mr. Bertsch is no longer with the Division.

• **Keith K. Kesling,** *Frigidaire Division, Dayton, Ohio, for a Refrigerating Apparatus, No. 2,692,809, issued October 26.* This patent relates to gaskets for sealing the mating edges at a mullionless joint between two side-by-side mounted doors on a cabinet, so that either door may be opened without opening the other door.

Mr. Kesling is project and design engineer in the Research and Future Products Engineering Department of Frigidaire. Originally employed in 1944 as a junior clerk in the Tool Design Department, Mr. Kesling advanced through regular promotions to appointment to his present position in 1951. He attended University of Dayton and Dayton Art Institute. This patent is



connected with Mr. Kesling's work on the design and development of a twin-door refrigerator.

• **Edmund F. Schweller and James W. Jacobs,** *Frigidaire Division, Dayton, Ohio, for a Slicing and Storing Device, No. 2,692,429, issued October 26.* This patent relates to a portable butter slicer adapted to be held above cooking receptacles on a range and operated by one hand to cut and discharge pats of butter into the receptacles.

• **James W. Jacobs,** *Frigidaire Division, Dayton, Ohio, for an Electrical Apparatus, No. 2,695,344, issued November 23.* This invention relates to a switch in which the transmission of vibrations to the bellows is minimized by a lost motion connection between the bellows and the snap action switch mechanism.

Mr. Schweller is assistant chief engineer of Frigidaire. He was originally employed by this Division as a draftsman and after serving in this position was promoted to project engineer. Subsequent promotions, prior to his present position, included section engineer and manager of the Household Engineering Department. His technical work at Frigidaire has included developmental work on aluminum-foil insulation and on metal shell and one-piece porcelain refrigerators. He is presently concerned with research and future-product development. This is the thirty-third patent granted as a result of Mr. Schweller's work in the field of refrigeration and air conditioning.

Mr. Jacobs serves as a section engineer in the Engineering Department of Frigidaire, where he is currently engaged in the development of electric controls for refrigeration and automobile air conditioning. Since joining the Frigidaire Patent Department as a draftsman in 1937, Mr. Jacobs has progressed to tracer (1941), to layout man (1943), to project engineer (1946), to senior project engineer (1950), and to his present position (1953). He received the B.S.M.E. degree from University of Dayton in 1954.

• **Sylvester M. Schweller,** *Frigidaire Division, Dayton, Ohio, for a Dual Evaporator Air Cooling Apparatus, No. 2,692,481, issued October 26.* This patent relates to a window-mounted air conditioner in which two refrigeration units are provided and in which thermostatic controls start and stop the units in stages, depending upon the refrigeration requirements.

At the time of his death in August 1953, **Mr. Schweller** had been director of engineering at Frigidaire for three years. He joined the Dayton Engineering Laboratories Company in 1916 as a draftsman. In 1925 he became general foreman in charge of all Frigidaire assembly operations. Two years later he was appointed superintendent of Frigidaire's Taylor Street plant and in 1937 was named chief engineer.

• **James L. Arthur,** *Allison Division, Indianapolis, Indiana, for a Gas Turbine Fuel Igniter, No. 2,693,082, issued November 2.* This patent pertains to an igniter for gas turbine combustion chambers in which the electrodes are shielded from the fuel spray by an air cooled shroud.

Mr. Arthur is general superintendent of the Electronics and Parts Test Laboratory at Allison. In 1916 Mr. Arthur joined the Remy Electric Company, which later became Delco-Remy Division, as a laboratory engineer. In 1942 he transferred to Allison Division as an ignition electrical engineer. His previous work at Delco-Remy was on the design of ignition distributors, vacuum advance distributors, and associated automobile equipment. Mr. Arthur is a member of the Society of Automotive Engineers.

• **John P. Hobart,** *Chevrolet Motor Division, Central Office, Detroit, Michigan, for a Gearshift Lever, No. 2,693,117, issued November 2.* This patent relates to a transmission shift lever and to a spring fastener means which is employed in securing the lever to the shift rod.

Mr. Hobart serves as a project engineer with Chevrolet Motor. He started with Chevrolet as a designer in 1939. Previously, he had been a designer at Oldsmobile Division from 1929 to 1932 and he had automotive experience with several other firms. University of Cincinnati granted Mr. Hobart the electrical engineering degree in 1921. He has

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.

worked on the Powerglide and Hydra-Matic automatic transmissions and, currently, is concerned with developmental work on special transmissions and transmission controls. This is the second patent granted on the basis of Mr. Hobart's work with automotive components. He is a member of the Society of Automotive Engineers.

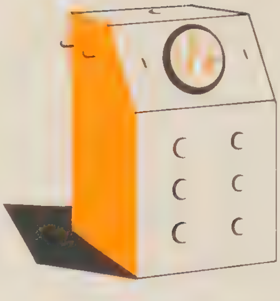
• **Francis H. McCormick**, *Frigidaire Division, Dayton, Ohio, for a Domestic Appliance, No. 2,693,523, issued November 2.* This patent covers a frying griddle for use on a surface heating unit of a range. The griddle is interlocked with the unit so as not to slide off the range and is rotatable relative to the unit.

Mr. McCormick is assistant chief engineer at Frigidaire. He joined the Division in 1936 as a range engineer, in 1939 was made manager of the Appliance Engineering Department, and in 1942 was promoted to his present position. In this capacity, he is responsible for the design of Frigidaire products including electric ranges, washers, dryers, water heaters, and other new appliances. This work has resulted in more than forty patents. Mr. McCormick received the B.S.E.E. degree from Washington State College in 1915.

• **John B. Wheatley and Arthur W. Gaubatz**, *Allison Division, Indianapolis, Indiana, for a Lubrication System, No. 2,693,248, issued November 2.* This patent covers a lubrication system for a gas turbine in which the oil is supplied and part is returned through the turbine shaft.

Mr. Wheatley serves as assistant chief engineer at Allison. He received both the A.B. degree in mechanical engineering and the master of engineering degree in aeronautics from Stanford University in 1929 and 1930. He joined Fisher Body Division in 1943 as an aeronautical engineer. In 1945 he transferred to Allison Division and was promoted to assistant chief engineer of that Division in 1951. He is a Fellow of the Institute of the Aeronautical Sciences.

Mr. Gaubatz is senior project engineer in the Experimental Engineering Department at Allison. He received the B.S. degree in 1920 from University of Wisconsin. He was originally employed in 1928 at the Buick Motor Division, Flint, Michigan, as a draftsman in the Experimental Engineering Department. He was transferred in 1940 to Allison. He is a member of Pi Tau Sigma and Tau Beta Pi.



• **David A. Galonska and William L. Reid**, *Saginaw Steering Gear Division, Saginaw, Michigan, for a Transmission Control, No. 2,693,713, issued November 9.* This invention relates to a transmission control linkage having a hand lever pivoted at the top of the steering column for axial and rotary movement which is connected to a concentrically mounted control tube having a particular cam mechanism arranged so that axial movement of the hand lever will actuate one control lever and rotary movement will actuate another control lever.

Mr. Galonska serves as a senior project engineer at Saginaw Steering Gear. In this capacity, he is concerned with all applications of ball-bearing and screw and nut assemblies. Mr. Galonska started with Saginaw Steering Gear in 1940 as a tool designer and transferred to the Product Engineering Department in 1943 as a designer. He also served for three years as experimental engineer-in-charge of the Physical Test Laboratory and model shop before appointment as project engineer in 1952. Mr. Galonska was appointed senior project engineer in charge of actuator engineering in 1954. Many of his projects were concerned with the design and development of jacks, splines, gearshift mechanisms, and bi-directional brake devices.

Mr. Reid is no longer with the Division.

• **Clarence H. Jorgensen and Fred E. Aseltine**, *Rochester Products Division, Rochester, New York, for a Charge Forming Device, No. 2,694,558, issued November 16.* This patent is related to the automatic choke mechanism of a charge forming device in which an unbalanced choke valve is freely movable by the entering air to different positions as determined by a stop movable by a thermostat and engine suction, the stop member also being positioned mechanically by the throttle.

Mr. Jorgensen has served since 1944 as chief research engineer of the Research and New Product Development Department, Rochester Products. He is widely recognized as inventor of the automatic choke now used on most GM cars. He began his General Motors engineering career in 1932 as a development engineer in the Engineering Department of Delco-Remy Division. Mr. Jorgensen's research work in automotive, aircraft, domestic, and industrial appliances has led to more than one-hundred-fifty granted patents. He studied at the University of Wisconsin and the University of Michigan, and is a member of the S.A.E.

Mr. Aseltine is no longer with the Division.

• **Elmer Olson***, *Rochester Products Division, Rochester, New York, for a Carburetor, No. 2,694,560, issued November 16.* This patent covers the specific arrangement of the fuel supply passages of a carburetor, which are in the form of a U-tube one leg of which extends into the float chamber and the other to the idling fuel supply jets while the horizontal part of the passage supplies the main nozzle.

• **Frank W. Brooks**, *Moraine Products Division, Dayton, Ohio, for a Brake Wear Compensating Device, No. 2,695,078, issued November 23.* This patent concerns an adjusting device placed between adjacent ends of a pair of brake shoes to effect adjustment of the shoes relative to the brake drum automatically as the brake lining wears.

Mr. Brooks is a product engineer in the Engineering Department of Moraine Products. His initial employment with General Motors was as an inspector at Delco Products (1935). One year later he started in the Engineering Laboratory, was promoted to draftsman in 1938, and to designer in 1940. Mr. Brooks transferred to Moraine Products in 1942, was promoted to project engineer in 1946, and to product engineer in 1954. He was granted the B.S. degree in mechanical engineering from Case Institute of Technology in 1935. His technical affiliations include membership in the Society of Automotive Engineers. In addition, he is a registered professional engineer, State of Ohio.

• **Carl L. Clevenger**, *Delco-Remy Division, Anderson, Indiana, for Manufacture of Commutator Bars, issued November 23.* This patent covers a die assembly for forming a pair of commutator bars simultaneously

and includes a die in which two sections of bar stock are positioned and with which punches for shaping the bars co-operate. A lower punch enters the die to shape the lower ends of the sections and a second punch is then moved into alignment with the die and moved into the die from above to shape upper ends of the sections into proper form.

Mr. Clevenger is a senior engineer at Delco-Remy. He joined the Division 21 years ago as a utility man. In 1942 he was promoted to foreman and one year later was promoted to senior engineer, his present position.

• **Mearick Funkhouser and George A. Brundrett,** *Delco Products Division, Dayton, Ohio, and Chevrolet Motor Division, Central Office, Detroit, Michigan, respectively, for a Shock Absorber Valve, No. 2,695,034, issued November 23.* This patent concerns a two-way base valve mechanism for a shock absorber that is a free opening valve in one direction and has dual sequentially effective restrictions controlling fluid flow in the opposite direction.

• **George A. Brundrett,** *Chevrolet Motor Division, Central Office, Detroit, Michigan, for a Hydraulic Shock Absorber, No. 2,695,079, issued November 23.* This patent pertains to a direct acting hydraulic shock absorber having one degree of resistance to movement in a given range of movement and a second greater degree of resistance to movement as the range of movement increases.

Mr. Funkhouser is chief engineer in the Engineering Department at Delco Products. In 1933 Mr. Funkhouser started at this Division as an inspector. He was promoted through the positions of laboratory engineer in the Shock Absorber Laboratory in 1933, senior design engineer in 1942, section engineer in 1944, and assistant chief engineer in 1945, to chief engineer, his present position, in 1951. Mr. Funkhouser earned the mechanical engineering degree in 1932 from Cornell University. He is a member of the Society of Automotive Engineers.

Mr. Brundrett is senior experimental engineer in the Vehicle Development Group of Chevrolet's Central Office. Mr. Brundrett originally started with Delco Products Division in 1946 as a junior engineer. After promotions to experimental engineer (1949) and senior experimental engineer (1952), he transferred to Chevrolet Central Office as a project engineer in June 1952. He was promoted to his present position in 1954. Mr. Brundrett earned the B.S.M.E. degree from University of Michigan, Ann Arbor, in 1944. He is a member of the S.A.E. The work related to these two patents was completed while Mr. Brundrett was connected with Delco Products.

• **Nolan A. Didion,** *Styling Section, Detroit, Michigan, for a Refrigerating Apparatus Having a Hydrator Receptacle, No. 2,694,906, issued November 23.* This patent relates to a hydrator pivotally mounted on the food storage compartment door of a refrigerator cabinet. When the hydrator is moved into a horizontal plane relative to the door, its top serves as a transfer or rearrangement ledge at the front of the food compartment.

Mr. Didion is a creative designer in the Product and Exhibit Design Studio of the Styling Section. Presently, he is concerned with exhibits for the 1955 Motorama. Mr. Didion came to General Motors five years ago as a junior designer in the Styling Section and was promoted to designer in 1951, to senior designer in 1952, and to creative designer, his present position, in 1953. He holds a degree in industrial design from the Art Center School in Los Angeles, California (1950). From 1942 until 1945 Mr. Didion served in the Air Corps as a draftsman-designer.

• **Howard M. Geyer* and Robert C. Treseder,** *Aeroproducts Operations of Allison Division, Dayton, Ohio, for a Submerged Motor-driven Pump and Fluid Pressure System for Variable Pitch Propellers, No. 2,695,070, issued November 23.* This patent relates to an electric motor-driven feathering pump assembly for a variable pitch propeller wherein the pump and motor are mounted in a rotatable reservoir containing hydraulic fluid.

Mr. Treseder is assistant to the chief engineer of the Aeroproducts Operations of Allison. He joined Aeroproducts in 1946 as a senior engineer and was promoted to his present position in 1953. He is currently engaged in developmental work on gas turbine propellers and actuators for aircraft-control surfaces. A graduate electrical engineer from University of Utah (1937), his work has resulted in four patents and numerous papers published in connection with his work on propellers, actuators, and electronic synchronizers.

• **Helmuth Guentsche and Laurence A. Nelson,** *GMC Truck and Coach Division, Pontiac, Michigan, for a Hydraulic Torque Converter Transmission, No. 2,694,950, issued November 23.* This patent relates to an angle-drive or V-drive transmission of the type used on GM buses and covers a particular design and arrangement of the hydraulic torque converter, forward and reverse gears, and the clutches which drive the transmission either through the torque converter or direct.

Mr. Guentsche is drafting supervisor in the Engineering Department of GMC Truck and Coach. He joined this Division in 1923 when it was known as the Yellow Cab Manufacturing Company. (In 1943 it was named GMC Truck and Coach Division.) Mr. Guentsche has been drafting supervisor since 1945 and, currently, he is concentrating on transmission development. The Technical University of Berlin in Charlottenburg, Germany, granted him a degree in engineering in 1923. This is the first patent granted as a result of Mr. Guentsche's work with hydraulic torque converter transmissions. He is a member of the S.A.E.

Mr. Nelson is no longer with the Division.

• **Paul L. Schneider,** *Delco-Remy Division, Anderson, Indiana, for an Air Circulating Apparatus, No. 2,694,970, issued November 23.* This patent pertains to an air circulating apparatus for use with an automotive vehicle in which the blower system for the heater is controlled by air flow passing through the air intake duct so that the blower is rendered inoperative when the vehicle is operating at high speeds and is rendered operative when the vehicle is stationary or operating at low speeds.

Mr. Schneider is section engineer of heavy duty equipment at Delco-Remy, a position he has held since 1952. Since coming to General Motors in 1921 as a trainee for service engineer, he has worked as process engineer, shop foreman, assistant foreman, supervisor of the Engineering Laboratory, and development engineer. His work on automotive electrical parts has resulted in 17 granted patents in this field. His formal education was obtained at The Ohio State University where he received his degree in mechanical engineering in 1921.

The Engineering Behind Allison's Vertical Take-off Aircraft Exhibit

By WALTER R. MYERS and
CLAIR J. HANOVER
Allison Division

The engineering task: to show technological advancement in an exhibit

Before aircraft could be made to operate from a point—rather than a runway—considerable engineering progress had to be made. First came the helicopter and, recently, a *vertical take-off* or *VTO* aircraft with a turbo-prop engine. Allison Division's engineers, drawing on an immense and growing knowledge of turbine power for aircraft engines, developed the power plant for the VTO, which is an important advancement in aviation. To develop an exhibit which would dramatize to the public the versatility of this new type of military flight also required engineering skills. An animated, three dimensional exhibit shows quite authentically how the VTO aircraft operates in a typical military application. And the display itself is typical of the many in the 1955 GM Motorama and those in Allison's own Powerama. Any member of the public may witness the entire VTO presentation simply by pressing a button.

Fig. 1—This display seeks to show a realistic Marine assault-landing situation involving both air and sea transportation, and features the VTO aircraft—the Convair XFY-1 fighter and the Lockheed XFV-1 fighter—which can take off and land vertically. The power units for the display, along with synchronized operating relays, timers, and microswitches, are concentrated behind the panel in the foreground. Each of the two full-size equivalents of the scale-model VTO aircraft in the display is powered by a twin-turbine 5,850 hp Allison T40 turbo-prop engine, shown in scaled-down outline on the right. The Convair R3Y-2 "Flying LST" aircraft shown is also powered by Allison T40 engines, driving contra-rotating Aeroproducts propellers. Six other military aircraft types also use Allison turbo-prop power.

The public has an opportunity to study advances in engineering, research, and design in the annual GM Motorama, which opened in New York City in January and will end a tour of five cities in Boston during the period April 23 through May 1. Each of the exhibits, supplied by participating GM organizations, required considerable engineering design and developmental work before it could convey an understandable technical message to the hundreds of thousands who would eventually view it. In New York City the attendance this year was more than 215,000.

Typical of these exhibits, which are an important part of the Motorama, is the animated *vertical take-off* or *VTO* aircraft display sponsored by Allison Division (Fig. 1). Here, because the opportunity to keep the public advised of technological progress is linked with a need for developing materials for the training of the Division's own personnel, Allison's Department of Public Relations maintains a technical staff and a shop. The work of developing and fabricating the exhibit was assumed by this Department, which also maintains and operates the Division's own year-'round technological progress exhibition called the Powerama.

The VTO exhibit soon will become a part of the Powerama, which is regularly visited at Allison's Plant 3 in Indianapolis by school, civic, military, and other groups. In the case of the VTO display, the basic requirement was to dramatize the performance of one of the latest military aircraft types. Allison's contribution to the VTO lies mainly in its twin-turbine 5,850 hp T40 turbo-prop engine.

Establishing the Requirements

When the project was begun in June 1954, the free-flight tests of the VTO had not been completed. Several preliminary sketches of an overall three dimensional exhibit were studied and the final plan called for two separate model VTO's—as there are two manufacturers who use the Allison engine—participating in a mock Marine assault landing. The VTO's would be made to simulate an authentic flight and landing plan. Animation would include even operation of the model planes' contra-rotating propellers. A sound track would carry background noises and a narrative. In the meantime, flight tests were conducted, and the paths the VTO traced as it took off, flew, and landed were observed.

While this plan was being solidified, the tentative dimension allotments of the exhibit came through—10 ft wide by 4 ft deep by 7 ft high. Preliminary drawings were made of all working parts and the electrical design was begun.

The Completed Exhibit

In the exhibit, completed early in January 1955, the two aircraft are repre-

sented by miniature scale models. These are fastened to steel tubing which is attached to a steel block that travels in a slotted track made of Micarta, providing a distortion-free and smooth surface. The track is machined into the shape of the desired flight pattern and the steel block is carried by an endless ⅜-in. bicycle chain which is made to follow the track contour by means of idler sprockets into which ball bearings are custom-fitted.

The viewer has but to press a button and the exhibit completes a 53-second animated demonstration, explained by tape-recorded narrative. (Twenty-four duplicate tapes were made to insure an adequate replacement supply.) One VTO model starts its engine and rises almost directly upward, then levels off. As it disappears, a second VTO model appears from the opposite side, moves toward the landing point and, just before landing, pulls upward into a two second stall and descends vertically. The synchronized narrative ends two seconds after the propellers stop rotating. Then a holding relay keeps the push button ineffective for 20 seconds and the entire demonstration can be repeated.

All of the unusual engineering in the exhibit is concealed from viewers. Even the tubing which supports the model planes is made crank-shaped so that the background scenery may be overlapped to hide the track. Controlled spotlighting is used to direct viewers' interest to important parts of the demonstration as they are mentioned in the narrative. All of the animation, lighting, and narrative are controlled by an electronic system consisting of motors, relays, timers, and microswitches mounted on the track, and by one thermal-delay relay.

Summary

The VTO exhibit—in making a realistic demonstration for the public—is a case example of an engineering project which dramatizes an immensely larger engineering project. The standard elements—analyzing the problem, applying past knowledge and adding new techniques in the solution, and ending with a successfully completed project—are repeated in almost every major and minor technical project undertaken by a technical organization. For the GM Motorama, the elements were carried forward simultaneously at widely scattered locations—as many times as there were exhibits introduced into the show.

Recent Speaking Engagements Filled by GM Engineers

Appearances at the 1954 Annual Meeting of the American Society of Mechanical Engineers and at the 1955 Annual Meeting of the Society of Automotive Engineers highlight the speaking engagements filled by GM engineers during recent months. Presented below is a listing of the GM individuals who spoke at these events, together with a summary of other talks made during the same period before educational, technical, and other groups.

Robert J. Richards, project engineer at AC Spark Plug Division, spoke at a meeting of the Society of Automotive Testers of America on October 8 in Chicago, Illinois. The subject of his talk was fuel pump history, functions, and methods of field testing.

Walter F. Eitel, general supervisor of the Methods, Layout, and Tool Design Department, and **Robert N. Smith**, supervisor—methods and plant layout, both of AC Spark Plug, outlined "The Application of Methods to Job Improvement" before the Saginaw Valley Chapter of the National Office Managers Association meeting on December 1 in Frankenmuth, Michigan.

On January 14 **Martin J. Caserio**, chief engineer—automotive products, AC Spark Plug, was a jury member on the students' latest design project at Massachusetts Institute of Technology in Cambridge, Massachusetts.

On December 1, in St. Louis, Missouri, **R. S. Hall**, head of the Preliminary Design and Development Section of the Turbo-Jet Engineering Department of Allison Division, described "Propulsion Systems for Supersonic Aircraft" before a meeting of the Institute of the Aeronautical Sciences.

R. R. LaMotte, engineering manager of Aeroproducts Operations of Allison Division, lectured on "Aeroproducts Turbo-Propeller Installations" at the December 9 meeting of the Institute of the Aeronautical Sciences, held in Dayton, Ohio.

P. N. Bright, group project engineer in the Stress Analysis and Weight Control Section of the Power Turbine Engineering Department of Allison, spoke on "The Structural Design Problems in Gas Turbine Engines" before the January 25 meeting of the I.A.S. in New York City.

T. W. Gillespie, chief test pilot at the Kansas City plant of Buick-Oldsmobile-Pontiac Assembly Division, recently completed two speaking engagements. On December 9, before the Eastern Chapter of the Kansas Society of Professional Engineers meeting in Kansas City, he described "Flight Testing the F-84F."

On December 14 he addressed members of the Society of Automotive Engineers touring the B.O.P. Kansas City plant. He described "The Organization and Operation of the Flight Test Department at B.O.P., Kansas City."

Charles E. Fausel, assistant superintendent of the Maintenance Department of Central Foundry Division's Danville, Illinois, plant, lectured on "The Opportunities in the Foundry Industry" before University of Illinois engineering students on November 12.

M. D. Varner, director of education and training at Central Foundry, Saginaw, Michigan, was a member of a panel discussion on the topic "Training of Engineers in Industry." The panel discussion was held during the December 7 meeting of the American Foundrymens Society at Ann Arbor, Michigan.

During the Annual Meeting of the American Telephone & Telegraph Company, held in Detroit on January 11, **Edward N. Cole**, chief engineer of Chevrolet Motor Division, described the features of the 1955 Chevrolet truck and new V-8 engine.

Robert K. Burns, director of education in Delco Products Division's Personnel Relations Department, lectured on "The

General Motors engineers speak on current topics on occasion before engineering classes and other engineering student groups. Requests for assistance in obtaining their services may be directed to the Educational Relations Section, GM Technical Center, Detroit 2, Michigan.

1954 Annual Meeting of the American Society of Mechanical Engineers

Several of General Motors technical personnel presented technical papers during the A.S.M.E. Annual Meeting, held in New York City from November 29 to December 3.

P. N. Bright, group project engineer in the Stress Analysis and Weight Control Section of the Power Turbine Engineering Department, Allison Division, presented the paper "The Structural Design Problems in Gas Turbine Engines."

Donald F. Flanders, senior statistician at Allison, talked on "The Interpretation of Ultrasonic Tests Through the Use of Statistical Quality Control Techniques."

Russell S. Hall, head of the Preliminary Design and Development Section of the Turbo-Jet Engineering Department of Allison, was a member of a panel discussion on turbo-props versus turbo-jets.

J. R. Ware, mechanical section engineer in Electro-Motive Division's Engineering Department, gave a commentary on the talk "Possibilities of Burning Lower Cost Diesel Fuels."

Harvey C. Charbonneau, senior technical instructor in the Industrial Engineering Department of General Motors Institute, gave the paper "The Application of Statistical Techniques to Simple Fixed Gage Design."

Kenneth Evashevski, senior project engineer, and **C. R. Bradlee**, project engineer, both of the Process Development Section, took part in a panel discussion on the plastic working of metals.

Arvid E. Roach, supervisor of bearing development; **Carl L. Goodzeit**, research engineer; and **Richard P. Hunnicutt**, research metallurgist—all of the Research Laboratories Division—jointly presented the paper "The Scoring Characteristics of Thirty-Eight Different Elemental Metals in High-Speed Sliding Contact with Steel."

Another paper prepared jointly by these three authors was "The Frictional Characteristics and Surface Damage of Thirty-Nine Different Elemental Metals in Sliding Contact with Iron."

Joseph B. Bidwell, assistant head of the Mechanical Development Department of the Research Laboratories, presented a discussion of the paper "A Re-evaluation of Surface Finish" by L. W. Chaney and C. H. Good.

Duane Joseph Heinlen, production superintendent at Ternstedt Division, outlined "The Inspection Procedures for the Acceptance or Rejection of Incoming Steel Shipments."

Career Development of Engineers" at a meeting of the Reserve Officers' Association—Wright Air Development Center. The meeting, held in Dayton, Ohio, was on December 15.

On December 16 Mr. Burns outlined "The Vocational Opportunities in Industry" to the junior and senior student body of Kiser High School in Dayton.

Leo J. Nartker, superintendent of quality control in the Inspection and Standards Department of Delco Products, was a speaker at the January 20 meeting of the Dayton Section of the American Society for Quality Control. He discussed "Quality Control Applications on Motors and Generators."

John J. May, engineer-in-charge of combustion and forward development in Detroit Diesel Engine Division's Engineering Department, spoke before the January 10 meeting of the Los Angeles Section of the S.A.E. He discussed "The Combustion Development of the Model 71 Engine."

E. W. Scheibe, senior engineer, and **Louis J. VanSlooten**, customer contact representative, both of the Engineering Department of Diesel Equipment Division, spoke on "The Operation and Servicing of the Hydraulic Valve Lifter" during a meeting of the Carter Club, held in Detroit, Michigan, on November 30.

On November 18, during a joint meeting of the Association of American Railroads and the Diesel Engine Manufacturing Association, held in Elizabeth, New Jersey, **W. K. Simpson**, technical director—fuels and lubricants, Engineering Department, Electro-Motive Division, participated as a member of a panel discussion on "Diesel Fuels of the Future."

Alan S. McClimon, manager of the Sales Development Department of Euclid Division, addressed the Greater Heights of Cleveland Rotary Club on December 16. He explained "The Earth-moving Machinery Industry's Role in Meeting Our Nation's Needs for Highway Development."

H. V. Beckerleg, engineer-in-charge of the Engineering Laboratory at Fisher Body Division, spoke at the Fifth Annual Conference of the Society of the Plastics Industry, held in New York City on December 8. The title of his talk was "The Automotive Applications of Vinyl Resins."

During the period covered in this report, **Thomas D. Welch**, mechanical engineer-in-charge of the Facilities Planning and Works Engineering Department of Fisher Body's Flint, Michigan, plant, completed three speaking engagements. On December 6 Mr. Welch addressed the Flint Council of Social Agencies, describing "Water and Sewage Facilities for the Flint Area."

As head of the Sanitation Committee of the Flint Area Study Group, Mr. Welch read the Committee's status report before a general meeting of the group on January 5.

On December 2 **John Dolza**, engineer-in-charge of the Power Development Section of the General Motors Engineering Staff, addressed a meeting of the American Society of Mechanical Engineers, held at Notre Dame University in South Bend, Indiana. The title of his talk was "What You Should Know to Design Engines."

D. B. McCormick, section engineer in the Automotive Ordnance Group of the Engineering Staff, outlined "The Development and Engineering of a New Ordnance Vehicle to Specifications" before a group of the Naval Reserve Ordnance, meeting in Detroit on December 7.

Before the Rotary Club of Warren, Ohio, on December 22, **Charles L. Tutt, Jr.**, administrative chairman of the Fifth-Year and Thesis Programs at General Motors Institute, talked on "What's Ahead for Youth."

Maurice Platt, chief engineer of Vauxhall Motors, Limited, England, addressed the London graduates of the Institution of Mechanical Engineers on January 15 on the subject of future trends in automobile design. In his review, Mr. Platt selected his examples from recent motor vehicle developments, both in Europe and in the United States.

Gerald R. Broshar, field engineer in Guide Lamp Division's Engineering Laboratory, addressed the Evening Optimist Club of Anderson, Indiana, on November 22. The title of his talk was "The Development of the Guide Lamp Autronic-Eye Automatic Headlamp Control."

Four technical personnel in the Product Engineering Department of New Departure Division completed speaking engagements during the period covered in this report as follows: **M. T. Monich**, senior project engineer, appeared before Air Force personnel at Olmstead Air Force Base in Middletown, Pennsylvania, on November 18, describing "The Visual Inspection of Used Ball Bearings." On December 17 he discussed "The Lubrication Practices for Ball Bearings" at the Farrel-Birmingham Company in Ansonia, Connecticut.

"Ball Bearings for Antifriction Centers" was the title of the talk given by **T. W. Bakewell**, senior engineer, New Departure, at a sales conference held at the Ready Tool Company at Bridgeport, Connecticut, on December 9.

L. D. Cobb, manager of research and development, New Departure, took part in the Educational Symposium held at Oklahoma Agricultural and Mechanical College on December 14. Mr. Cobb talked on "Ball Bearing Application and Research."

At the November 5 S.A.E. Fuels and Lubricants Meeting held in Tulsa, Oklahoma, **Dr. Lloyd A. Withrow**, department head; **Wayne A. Daniel**, research physicist; and **Joseph T. Wentworth**, research engineer, all of the Research Laboratories Division's Fuels and Lubricants Department, presented a discussion of the paper "A Quick Look at Engine Combustion" by George Ball.

David L. Fry, supervisor of the Physics and Instrumentation Department of the Research Laboratories, addressed the Indiana Spectrographer's Society meeting in Indianapolis on December 13. The topic of his talk was "The Spectrographic Analysis of Oil."

1955 Annual Meeting of the Society of Automotive Engineers

The 1955 S.A.E. Annual Meeting—held in Detroit, Michigan, from January 10 through 14—marked the fiftieth annual meeting held by that Society. The following is a listing of General Motors technical personnel participation in the Meeting.

On January 10, the first day of the Annual Meeting, **L. E. Cummings**, assistant manager of product and material control in the Material Control Division of Delco Products Division, was a member on the panel discussion "A Manufacturing Cost Reduction Technique from the Design Board to the Shipping Room."

During the symposium on air pollution, **Fred G. Rounds**, senior research engineer; **Paul A. Bennett**, research engineer; and **George J. Nebel**, research engineer, all from the Fuels and Lubricants Department of the Research Laboratories Division, jointly presented the paper "Some Effects of Engine-Fuel Variables on Exhaust Gas Hydrocarbon Concentration."

As part of the same symposium, **Joseph T. Wentworth**, research engineer, and **Wayne A. Daniel**, research physicist, both in the Fuels and Lubricants Department, gave the paper "Flame Photographs of Light Load Combustion Point the Way to Reduction of Hydrocarbons in Exhaust Gas."

The same day, the paper "The Evaluation of the Energy Released During Preflame Reactions" was given by Messrs. Wentworth and Daniel and Professor Donald R. Olsen, Research Laboratories consultant from Yale University.

On January 11 **T. A. Boyd**, Research Laboratories consultant, delivered the paper "S.A.E. in Fuels and Lubricants—Yesterday, Today, Tomorrow."

John D. Caplan, supervisor in the Fuels and Lubricants Department, Research Laboratories, presented a discussion of the paper "Passenger Car Vapor Lock" by D. P. Heath, R. H. Thena, and Gilbert Way.

"The Study of Detergent Lubricating Oils by Electron Microscopy" was presented by **F. Agnes Forster**, special tester; **Stanley R. Rouze**, research physicist; and **William L. Grube**, supervisor, all of the Physics and Instrumentation Department, Research Laboratories.

At another session on January 11, **Martin J. Caserio**, chief engineer—automotive products, AC Spark Plug Division, presented a prepared discussion on the paper "Abrasive Wear of Piston Rings" by C. W. Watson, F. J. Hanly, and R. W. Burchell.

The third day of the Meeting, January 12, **Maurice Olley**, director of the Research and Development Section of Chevrolet Motor Division, spoke on "Progress in Passenger Cars."

The same day, **R. F. Sanders**, staff engineer in the Passenger Car Chassis Design Section of Chevrolet Motor, presented a paper on the new Chevrolet V-8 engine and **C. B. Leach**, assistant motor engineer, and **E. L. Widneler**, experimental engineer, both of Pontiac Motor Division, gave a paper on the new Pontiac V-8 engine.

On January 14 **D.K. Hanink**, supervisor, and **F. J. Webbere**, supervisor, both of the Research Laboratories' Metallurgy Department, in conjunction with **A. L. Boegehold**, assistant to the general manager of the Research Laboratories, presented the paper "The Development of a New Gas Turbine Super Alloy—GMR 235."

The paper "Engine Valves Improved by Aldip Coating" was prepared jointly by **Dr. R. F. Thomson**, department head, and **D. K. Hanink**, supervisor, both of the Research Laboratories Metallurgy Department; by **E. B. Etchells**, design engineer at Chevrolet Motor Division; and by **K. B. Valentine**, project engineer in the Metallurgical Section of Pontiac Motor Division.

Solution to the Previous Problem:

Determine the Shape of a Cantilever Spring of Minimum Stress for Door-Check and Hold-Open Application

By BARTHOLD F. MEYER
Ternstedt
Division

A shape is determined but no formula is available to check the stress

The cantilever spring comprising the check link of the door-check and hold-open mechanism must be capable of withstanding a high stress when deflected to its maximum amount during the opening of a car door. The minimum allowable width of the hook-end section is *0.75 in.* The specific shape of the spring which results after the minimum allowable width has been calculated is such that no ready formula is available to check the stress to which the spring is subjected. As a result, a deflection formula must be derived based on the area-moments method of calculating the deflection of a beam. This is the solution to the problem presented in the January-February 1955 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

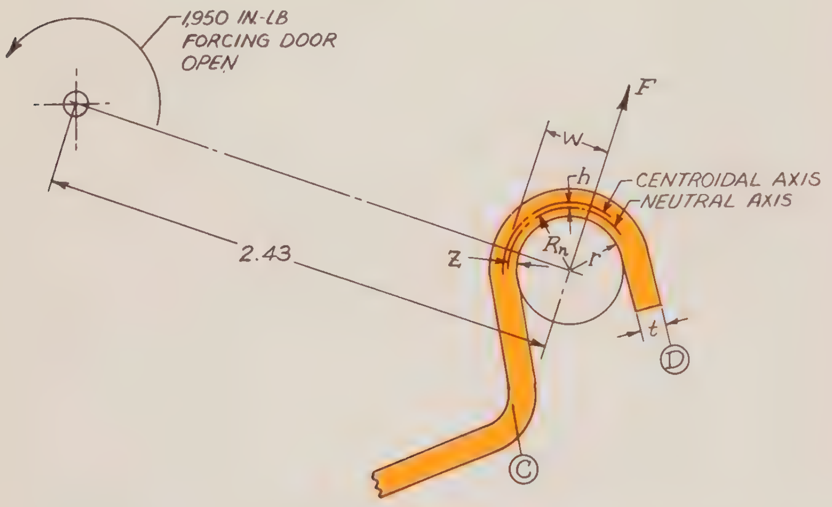


Fig. 1—The determination for the width of the hook-end section of the spring between points **C** and **D** while in the checking condition can be based on treating the section as a curved beam of rectangular cross section. The force F is exerted by the roller on the hook-end section and is due to the load tending to force the door open. The width of the hook-end section is based upon a formula for stress which is a function of the force F, the thickness of the spring, and the location of the neutral and centroidal axes.

The first step which Ternstedt Division engineers use in the solution to a problem of this type is to determine the force exerted by the roller on the hook-end section of the spring due to the load forcing the door open. When this force is known it is possible to calculate the minimum allowable width of the hook-end section capable of withstanding the maximum allowable stress of 145,000 psi.

Fig. 1 shows a view of the hook-end section of the spring, between points **C** and **D**, while in the checking condition. Since the maximum force tending to open the door is 1,950 in.-lb at the door-hinge center, and the radius of the roller's horizontal path of travel from the hinge center is 2.43 in., the force F exerted by the roller on the hook-end section is 1,950/2.43 or 803 lb. The direction of this force is as shown in Fig. 1.

If the hook-end section of the spring between points **C** and **D** in Fig. 1 is treated as a curved beam of rectangular cross section, the stress S can be given by the following equation:

$$S = Fwz/bthr \qquad (1)$$

where

S = maximum allowable stress in the hook-end section (145,000 psi)

F = force exerted by the roller on the hook-end section (803 lb)

w = distance from the neutral axis of the hook-end section to the line of force F (in.)

z = distance from the neutral axis to the extreme fiber (in.)

b = minimum allowable width of the hook-end section (in.)

t = thickness of the spring (0.125 in.)

h = distance from the neutral axis to the centroidal axis (in.)

r = radius of curvature to the inner concave surface of the hook-end section (0.25 in.).

If the above equation is transposed and set equal to b and the maximum stress of 145,000 psi is inserted, it is then possible to determine the minimum width of the hook-end section between points **C** and **D** which will meet the design requirements. Before this can be done, however, it is necessary to determine the unknown values for w, h, and z (Fig. 1).

The radius of curvature R_n, in inches, to the neutral axis of the hook-end section can be determined from the relationship:

$$R_n = t/\log_e (r + t/r).$$

Substituting in the known values

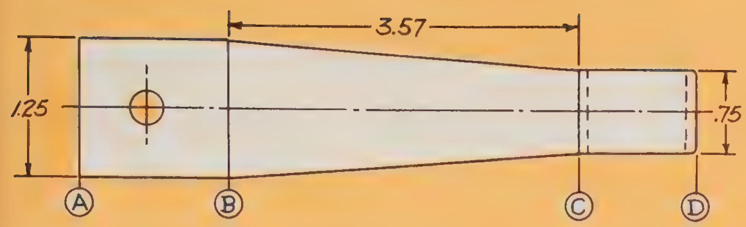
$$R_n = 0.125/\log_e (0.25 + 0.125/0.25)$$

$$R_n = 0.125/\log_e 1.5$$

$$R_n = 0.3082 \text{ in.}$$

The distance w from the neutral axis to the line of force F also is equal to R_n or 0.3082 in.

The centroidal axis for the hook-end section of the spring will be at the mid-point of the spring's thickness or 0.0625 in. The distance h, therefore, between



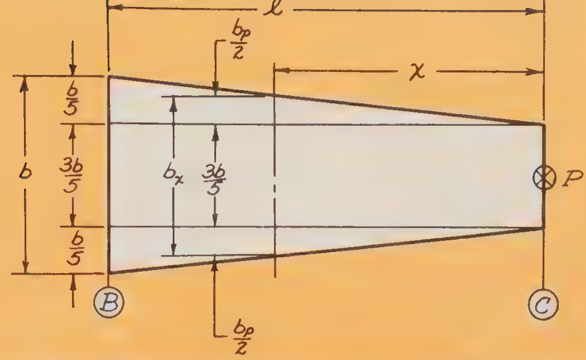


Fig. 2—The minimum allowable width of the hook-end section of the spring is found to be 0.75 in. The resulting trapezoidal shape of the spring between points **B** and **C** must be checked for the stress to which this section will be subjected while being deflected the maximum distance of 0.36 in.

Fig. 3—The shape of the spring between points **B** and **C** is such that the width varies along the length and, consequently, the value for the moment of inertia which is to be used in a formula for deflection must include the expression for spring width at any point X along the width. The above figure shows the trapezoidal section split so as to form one rectangle and two triangles. This serves the purpose of simplifying the calculations necessary to establish an expression for the width of the spring b in terms of x.

the neutral axis and the centroidal axis will be equal to:

$$h = r + (t/2) - R_n$$
$$h = 0.25 + (0.125/2) - 0.3082$$
$$h = 0.0043 \text{ in.}$$

The remaining unknown to be found is the distance z, in inches, from the neutral axis to the extreme fiber. This value can be found from the following relationship:

$$z = R_n - r$$
$$z = 0.3082 - 0.25$$
$$z = 0.0582 \text{ in.}$$

The minimum width b of the hook-end section between points **C** and **D** which will be able to withstand the load F and the maximum allowable stress can now be determined by transposing equation (1) to read:

$$b = Fwz/Sthr.$$

Substituting in the known values

$$b = 803\ (0.3082)\ 0.0582/145{,}000\ (0.125)\ (0.0043)\ 0.25$$
$$b = 14.4036/19.4844$$
$$b = 0.739 \text{ in.}$$

The maximum width of the spring, 1.25 in. between points **A** and **B**, and the required length of the spring, 3.57 in. between points **B** and **C**, were previously stated as part of the design requirements. These two dimensions, therefore, and the minimum width of the hook-end section, which is rounded off to be 0.75 in., establish a spring which is trapezoidal in shape (Fig. 2).

Calculations must now be made to check the stress to which the trapezoidal spring section between points **B** and **C** will be subjected while being deflected the required distance of 0.36 in.

The deflection of 0.36 in. will be caused by a load P acting on the end of the trapezoidal section or along a line through point **C** (Fig. 3). If this load were known it would then be possible to calculate the stress of the spring section between points **B** and **C**. The trapezoidal spring section is not one of standard form for which a deflection formula (having a variable, the load P) is readily available. It is necessary, therefore, to derive a deflection formula to suit the specific shape represented.

The deflection for a beam can be found by two methods: (a) by double integration and (b) by area-moments. The derivation for a deflection formula for the trapezoidal spring section, which will be treated as a cantilever beam, will be based on the area-moments method.

The basic equation for determining the deflection of a uniform beam, between the points **B** and **C** of the spring section, by the area-moments method is:

$$y = \int_B^C Mxdx/EI \qquad (2)$$

where

y = maximum deflection at a distance x from the end of the beam due to a load P (in.)

M = moment about **B** of area of moment diagram between **B** and **C**. Mdx is an element of this moment diagram (in.-lb)

E = modulus of elasticity for the spring steel material [$30(10)^6$ psi]

I = moment of inertia of the trapezoidal section in question (in.^{4}).

The moment of inertia of an area is a function of its width and thickness. From Fig. 3, which represents the section of the trapezoidal spring between points **B** and **C**, it can be seen that while the thickness is constant the width varies as x varies and, therefore, the moment of inertia also varies along the length of the spring section. Before a value for I can be used in equation (2) it will be necessary to derive an expression for the width of the spring as it varies along the length.

From Fig. 3, and by similar triangles:

$$2\ (b_p/2)/x = 2(b/5)/l.$$

Simplifying,

$$b_p = 2\ bx/5l.$$

Also,

$$b_x = 3b/5 + 2b_p/2$$
$$b_x = 3b/5 + 2bx/5l = (3bl + 2bx)/5l.$$

To find the deflection y at the end of the spring (point **D**) due to the load P, equation (2) can be rewritten in the following manner:

$$y = \int_0^l (Px)xdx/EI.$$

For a rectangular section, $I = bt^3/12$. The expression for I can be changed to suit the trapezoidal section by inserting for b the relationship previously developed for b_x. Therefore,

$$y = \int_0^l (Px)xdx/E\ (b_x\ t^3/12)$$

$$y = \int_0^l 60\ Plx^2\ dx/Ebt^3\ (3l + 2x).$$

Simplifying,

$$y = 60\ Pl/Ebt^3 \int_0^l x^2\ dx/3l + 2x.$$

Integrating the above expression between the limits results in the following expression:

$$y = 4.48\ Pl^3/Ebt^3. \tag{3}$$

The deflection for the spring is known (0.36 in.). It is necessary, therefore, to transpose equation (3) and solve for the load P so that this value can be inserted into an equation for the stress to which the trapezoidal spring section between points B and C is subjected. Transposing equation (3) and solving for P results in:

$$P = Eybt^3/4.48\ l^3$$

$$P = 30(10)^6\ (0.36)\ (1.25)\ (0.125)^3/4.48\ (3.57)^3$$

$$P = 129.36 \text{ lb.}$$

The maximum stress S to which the trapezoidal spring section will be subjected while being deflected 0.36 in. by a load of 129.36 lb can be calculated from the following formula:

$$S = 6Pl/bt^2.$$

Substituting the known values

$$S = 6\ (129.36)\ 3.57/1.25\ (0.125)^2$$

$$S = 141{,}825 \text{ psi.}$$

The above calculated stress is below the specified maximum allowable stress of 145,000 psi. The design, therefore, is satisfactory. If the stress had been above the maximum permissable, a change in design would be necessary. This change in design would have to be made either in the spring location or in the physical dimensions of the spring.

Summary

The use of a cantilever spring of varying width has resulted in reduced costs for material. The specific design has also resulted in a spring which is stronger and more durable than a spring of constant width. For example, if a spring were used with a constant width of 1.25 in. the resulting stress would be 159,000 psi, which is well above the design specifications. Actual tests also have shown that a spring of constant width when used for this door-check and hold-open application had a life expectancy of 20,000 cycles, while a spring of varying width resulted in a life expectancy in excess of 50,000 cycles.

A Typical Problem in Engineering:

Determine the Maximum Tensile Stress in a Jet Aircraft Turbine Shaft with Over-hung Turbine Wheels

An aircraft in flight undergoes, at various times, three basic flight maneuvers—rolling, pitching, and yawing. Each of these flight maneuvers, which takes place about the aircraft's pitch, roll, and yaw axes, causes a moment of force about that particular axis. This moment, in turn, has a bearing on the loads and, consequently, the stress to which the aircraft's component parts are subjected. The engineer, when calculating the stress in an aircraft's component parts, must take into consideration the moment of force caused by the flight maneuvers. This moment of force imparts a stress that is in addition to the stresses encountered by the aircraft while in normal flight. The problem presented here is to determine the maximum tensile stress in a jet engine turbine shaft with over-hung turbine wheels. An important step in the solution to the problem is the application of a moment equation which takes into consideration the gyroscopic action of the spinning turbine wheels due to the aircraft's yawing flight maneuver. The solution to this problem will appear in the May-June 1955 GENERAL MOTORS ENGINEERING JOURNAL.

A TYPICAL problem encountered in the analysis of jet aircraft engine components concerns the determination of the maximum stress in the engine's turbine shaft. The problem is made somewhat more complex when the design calls for the shaft to have over-hung turbine wheels. Fig. 1 shows a portion of a jet engine's turbine shaft, bearings, and over-hung turbine wheels.

The stress analysis for a jet engine turbine shaft with over-hung turbine

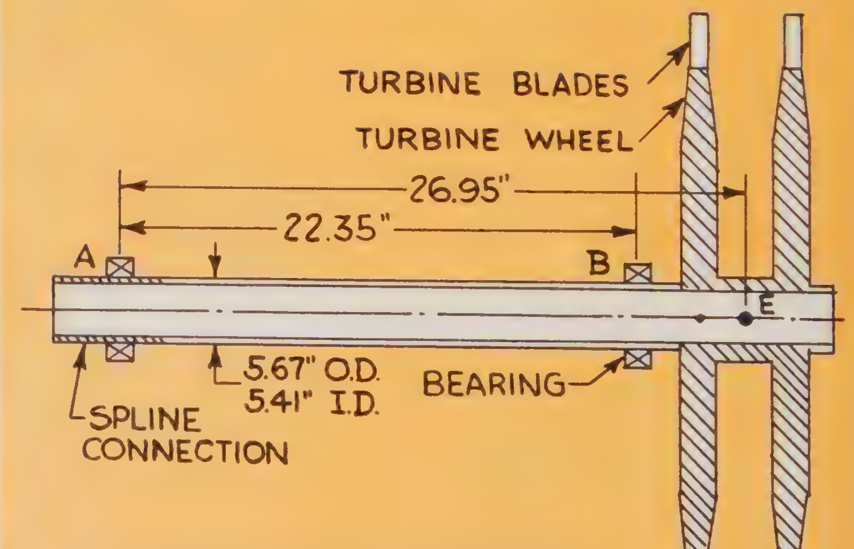


Fig. 1—An important factor which must be considered in the analysis of a jet engine's turbine shaft having over-hung turbine wheels is the moment of force applied to the shaft's bearings. This moment of force results from the gyroscopic action of the spinning turbine wheels when the aircraft turns horizontally about its vertical axis (yaws).

By ROBERT W. LEWIS
Allison
Division

An aircraft's yaw creates additional stress consideration

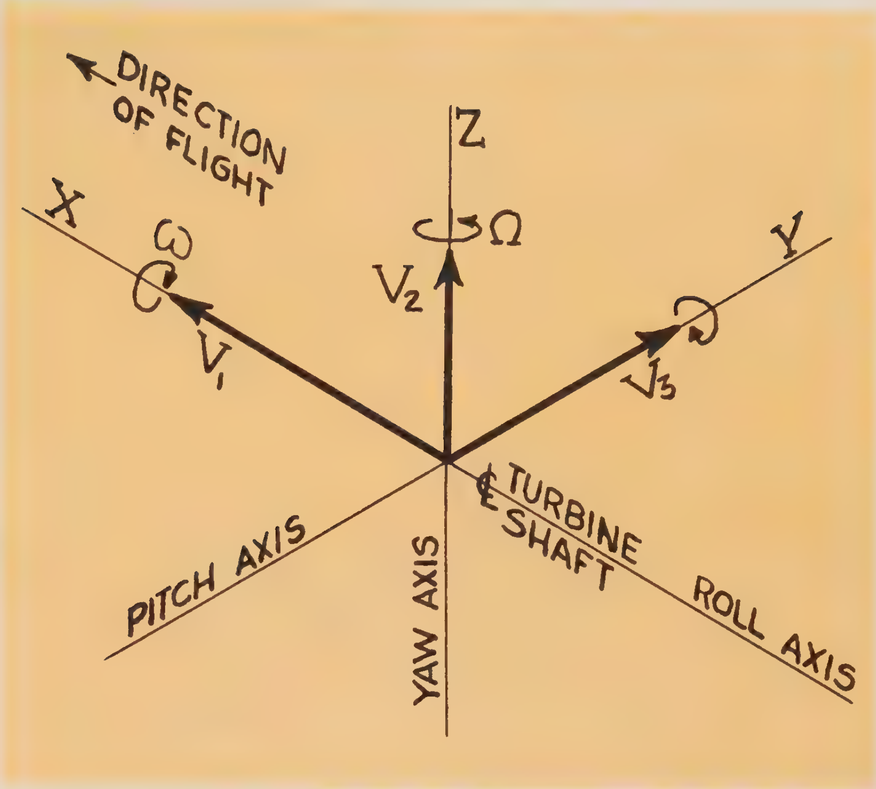


Fig. 2—The three flight maneuvers which an aircraft undergoes may take place about the aircraft's longitudinal or roll axis, pitch axis, or yaw axis. Each of the maneuvers causes a moment of force to be imparted to the aircraft's component parts. When a jet aircraft undergoing a yawing flight maneuver (turning horizontally about its vertical axis) is considered, a moment of force is imparted to the engine's turbine shaft bearings due to the gyroscopic action of the spinning turbine wheels. The moment of force may be represented by a gyroscopic moment vector V_3 which is the vector cross product of V_1V_2. The vector quantity V_1 is the angular momentum vector of the spinning turbine wheels rotating at an angular velocity of ω radians per second. The vector quantity V_2 represents the angular velocity of the XY plane rotating at Ω radians per second about the yaw axis.

wheels differs from the usual procedure for determining the maximum stress in a shaft not being used for aircraft application purposes. The difference that exists is due to *flight maneuver loads* which are imposed on the shaft. The flight maneuver loads are caused by the rolling, pitching, and yawing movements of the aircraft while it is in flight. These three movements take place about the longitudinal or roll X, pitch Y, and yaw Z axes of the aircraft (Fig. 2).

One of the loading conditions caused by the aircraft's flight maneuvers is the bending moment applied to the turbine shaft bearings. This moment is produced by a moment of force caused by the gyroscopic action of the spinning turbine wheels when the aircraft is yawing.

Referring to Fig. 2, the vector V_1 directed along the X axis represents the angular momentum vector of the spinning turbine wheels rotating at an angular velocity of ω radians per second. (The vector quantity, *angular momentum*, also is referred to as *moment of momentum* and sometimes *spin momentum*). The vector quantity V_2 represents the angular velocity, in Ω radians per second, with which the XY plane rotates about the Z or yaw axis. If the right-hand rule is applied, the direction of the moment vectors V_1 and V_2 will be as shown in Fig. 2. The gyroscopic moment applied to the turbine shaft due to the action of the spinning turbine wheels when the aircraft is yawing can be represented vectorially as V_3 which is equal to the vector cross product of V_1V_2.

The vector quantity V_1 is equal to $I\omega$, following from a fundamental idea of mechanics that the angular momentum with respect to an axis of a body which is rotating about that axis is the product of the moment of inertia I of the body multiplied by its angular velocity. In this particular case, I equals the mass moment of inertia of the turbine wheels and ω equals the angular velocity of the turbine wheels. The angular velocity of the XY plane about the yaw axis was previously stated as Ω radians per second. Vector V_3 which represents the *gyroscopic moment vector* will be equal, therefore, to V_1V_2 or $I\omega\Omega$.

The previous explanation should not be considered as a completely thorough analysis of the gyroscopic moment. It is intended only as background information relating to the problem. For a complete derivation of the gyroscopic moment equation, engineering mechanics and aircraft dynamics textbooks should be consulted.

Problem

The problem is to determine the maximum tensile stress in a hollow jet engine turbine shaft with over-hung turbine wheels, as shown in Fig. 1. In the solution to the problem stresses due to torsion, bending, and shear should be considered. Calculations pertaining to the shaft's deflection should be neglected.

In the course of the problem's solution it will be necessary to consider the gyroscopic moment M_g applied to the hollow turbine shaft due to the aircraft's yawing flight maneuver. The equation for this moment is as follows:

$$M_g = (\omega\,\Omega\,I_p)\,12/g$$

where

M_g = moment of force applied to the turbine shaft due to gyroscopic action of the spinning turbine wheels when the aircraft yaws (in.-lb)

ω = angular velocity of the hollow turbine shaft (radians per second)

Ω = yaw velocity of the aircraft (radians per second)

I_p = polar moment of inertia of the turbine wheels (lb-ft^2)

g = gravitational conversion factor (32.2 ft/sec^2).

Additional information which is pertinent to the problem's solution is as follows:

(a) turbine wheel weight = 85 lb per wheel

(b) turbine wheel polar moment of inertia = 29.66 lb-ft^2 per wheel

(c) jet engine horsepower transmitted by the turbine shaft = 16,560 hp at a turbine shaft speed of 11,000 rpm.

The inertia loads due to the linear acceleration, in various directions, of the jet engine are specified in *G's*. For example, a 10*G* force is a force 10 times the force of gravity. For the conditions of this problem consider the following flight maneuver conditions:

(a) vertical load = 10*G's*

(b) aircraft yaw velocity = 3.5 radians/second.

The solution to the problem will appear in the May-June 1955 issue of the General Motors Engineering Journal.

The

DILWORTH STORY–

Electro-Motive Offers Book to ENGINEERING EDUCATORS

Engineering educators interested in the Diesel and Diesel-electric propulsion areas are invited to write for a complimentary copy of "The Dilworth Story," by Franklin M. Reck and containing a foreword by Charles F. Kettering. This 107-page book surveys the colorful self-made career of Mr. Richard M. Dilworth, pioneer developer of the Diesel locomotive.

Engineering professors and instructors may direct their requests for a complimentary copy of this recently released McGraw-Hill Book Company publication to

Department of Public Relations
Electro-Motive Division
General Motors Corporation
LaGrange, Illinois

Contributors to March-April 1955 Issue of

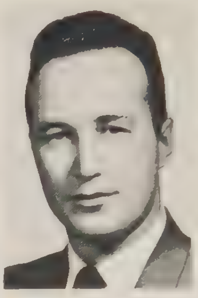
GENERAL MOTORS Engineering JOURNAL

PETER J. BAKER, co-contributor of "Empirical Methods Developed to Forecast Life of Self-enclosed, Grease-lubricated Ball Bearings," serves as a project engineer in the Product Engineering Department at New Departure Division, Bristol, Connecticut.

Mr. Baker came to New Departure in June 1948 as an engineer-trainee in the Personnel Department's training program. In December of that same year he was assigned to the Product Engineering Department's Physical Test Laboratory as a test engineer where he remained until his transfer and promotion to the Applications Section in February 1954 as a project engineer.

Included in Mr. Baker's past assignments have been developmental work on ball-bearing seals and various aspects of lubricant testing, which forms the background for his current paper. At present, he is principally concerned with ball-bearing applications for electric motors.

The University of Notre Dame granted him the B.S. degree in mechanical engineering in 1948, the same year that he joined General Motors. His technical affiliations include membership in the Society of Automotive Engineers and the American Society of Lubrication Engineers.



JEAN L. CARPENTER, contributor of "Patents May Be Used by the Engineer as an Excellent Source of Technical Information" and co-ordinator of this issue's "Notes About Inventions and Inventors," is a patent attorney in the General Motors Central Office Patent Section, Detroit, Michigan.

Mr. Carpenter is a graduate of the University of Michigan, earning the B.S.E. degree in naval architecture and marine engineering in 1948. Two years later he was granted the L.L.B. degree from the same University.

In October of 1950 Mr. Carpenter joined General Motors as a patent searcher in the Washington, D. C., office of the Patent Section. In early 1952 he transferred to the Central Office Patent Section and was made responsible for the preparation of patent applications, license agreements, and infringement questions connected with Electro-Motive Division.

Mr. Carpenter joined the Marine Corps in March 1943, serving as a radio gunner. In February 1944 he entered flight training with the U. S. Navy, separating in September 1945 as an aviation cadet.

His professional affiliations include membership in the Michigan Bar Association, American Bar Association, Michigan Patent Law Association, and the American Patent Law Association. In addition, Mr. Carpenter is a registered patent attorney and is a member of Phi Alpha Delta, legal fraternity.

Members of the engineering faculty of colleges and universities may receive the General Motors Engineering Journal regularly upon their request. Classroom quantities are also supplied regularly on request.

ALBERT C. DRECHSLER, contributor of "Fabrication of a Welded Steel Crankcase for a Light-Weight, Two-Cycle Diesel Engine," is master mechanic in the Manufacturing Department at Cleveland Diesel Engine Division, where he started his career in 1941 as a junior tool designer.

As a junior tool designer, just having received the B.S. degree in mechanical engineering from the Case Institute of Technology, he worked on the drawing board designing simple jigs and fixtures and gaining creative experience. His responsibilities increased quite rapidly and during World War II he contributed to the design of a tracer-controlled planer for producing helical blower rotors and did the major part of the design work on an automatic flame-cutting machine for producing air port holes in Diesel cylinder liners. Part of the latter work resulted in a patent on welding processes.

In 1950 Mr. Drechsler was made assistant master mechanic and two years later assumed his present duties. As master mechanic, his duties include supervision of tool design, plant layout, machine repair, and tool sharpening and, additionally, he makes recommendations on tool purchasing. His supervisory areas include the tool room, stores and cribs, and the pattern shop.

At Case, his thesis dealt with the design and vibration analysis of a valve train, a work which led to his election to Sigma Xi. Mr. Drechsler also is a member of the Society of Automotive Engineers and the American Welding Society.

CLAIR J. HANOVER, co-contributor of "The Engineering Behind Allison's Vertical Take-off Aircraft Exhibit," serves as electrical project engineer for Allison Division's year-'round technological exhibit, the Powerama. This collection of displays is designed, maintained, and operated as a part of Allison's Department of Public Relations.

Mr. Hanover has completed the electrical design and development of several Allison exhibits, principal among them—besides the VTO exhibit described in the current paper—being an arrangement of water faucets whose flow is synchronized to a model jet aircraft in varying conditions of operation. The faucets pour water in proportion to the jet engine's fuel consumption. Among his current projects is the application of silver-base, printed-circuit paint to narrative recording tapes. This tape moves over contactors and the silver completes an electrical circuit, thus providing a synchronizing means for an entire animated technical exhibit.

Mr. Hanover came to Allison in June 1952 after serving six years in teaching and curriculum-development capacities for electronics technician schools in New Jersey and Indiana. His instruction covered radio and television theory, mathematics through trigonometry, and radio and television maintenance. Earlier, he served one year as a junior engineer, mainly on the development of a cross-pointer indicator for a ground-controlled-approach landing system.

He earned the B.S. degree in radio engineering from Tri-State College in December 1945.

DAN H. JONES, contributor of "Reading Improvement in Industry Aided by Scientific Program," has served as senior instructor in the Psychology Section, English and Psychology Department of General Motors Institute, Flint, Michigan, since he joined the faculty of the Institute in April 1951.

Mr. Jones is now in charge of the reading improvement program conducted for engineering students at General Motors Institute. He is also chairman of the technical committee of General Motors for continued reading development and research and acts as consultant for General Motors Institute plant programs in reading improvement.

Mr. Jones earned both the A.B. degree in psychology in 1948 and the M.A. degree in 1949 from the University of Kentucky. He did further graduate work at Wayne University and is now completing his requirements for the Ph.D. degree at Michigan State College.

Before coming to General Motors, Mr. Jones had served as a psychologist at Herman Kiefer Hospital, Detroit, Michigan, where he organized training programs for handicapped persons as a part of their rehabilitation program.

His technical society affiliations include membership in the American Psychological Association, the Division of Business and Industrial Psychology, and the Michigan Industrial Psychologists.

C. W. LINCOLN, contributor of "A Summary of Major Developments in the Steering Mechanisms of American Automobiles," is chief engineer of Saginaw Steering Gear Division in Saginaw, Michigan. A native of Illinois, he was graduated from the University of Illinois in 1916 with the B.S.M.E. degree.

Before entering college, and during summer vacations, he worked as a draftsman with various Illinois companies. After graduation, two years in the Engineering Department of the Curtiss Aeroplane Company were followed by an instructorship at the University of Illinois. A later assignment as a civilian engineer (in aeronautics) with the Army was broken briefly by a term of enlisted service during the first World War.

After a short period with an Ohio engineering company, Mr. Lincoln went to Saginaw to join the Engineering Department of the Lufkin Rule Company, where he remained for 12 years. In 1932, he joined the Saginaw Steering Gear Division of General Motors as a tool and machine designer, serving later in various capacities in the Engineering Department.

At the beginning of the Division's armament production for World War II, he was appointed chief tool designer at the Machine Gun Plant, and was promoted to master mechanic at that Plant in 1944. In 1946 he was appointed assistant chief engineer of the Division, and in 1948 was appointed to his present position as chief engineer.

He has played major parts in the development of the well-known recirculating ball steering gear, and in the more recent and highly successful devel-

opment of power steering for automotive vehicles.

Mr. Lincoln is a member of Tau Beta Pi and of the Society of Automotive Engineers. He is the author of various papers on automotive steering and his work has led to several granted patents in that field.

BARTHOLD F. MEYER,

who prepared the problem "Determine the Shape of a Cantilever Spring of Minimum Stress for Door-Check and Hold-Open Application" and the solution appearing in this issue, is supervisor of the Mechanical Design Group, Product Engineering Department, Ternstedt Division, Detroit, Michigan.

Mr. Meyer joined Ternstedt Division in 1951 as a group leader in the Experimental Engineering Department. In 1953 he was promoted to his present position. Prior to joining Ternstedt, Mr. Meyer was associated with Lear, Incorporated, Grand Rapids, Michigan, where much of his work was concerned with the development of aircraft electro-mechanical equipment.

Pratt Institute in New York granted Mr. Meyer the B.S. degree in mechanical engineering in 1939. Three years later he entered the U. S. Army Air Force. He was separated from the Air Force with the rank of captain after serving as commanding officer and engineering officer of an aircraft service squadron. Upon separation from the service, Mr. Meyer undertook graduate study for a one-year period at Johns Hopkins University, Baltimore, Maryland.

Mr. Meyer's previous projects at Ternstedt include development of electro-mechanical actuators for window and seat operation and the design of miscellaneous mechanical components for automobile hardware products. At the present time, Mr. Meyer's work is concerned with the design and development of automobile hardware components to be used on future car models.

Two patents have been granted as a result of Mr. Meyer's work in the field of electro-mechanical design.

HARRY D. MARTIN,

co-contributor of "Empirical Methods Developed to Forecast Life of Self-enclosed, Grease-lubricated Ball Bearings," is chief physical test engineer in the Product Engineering Department at New Departure Division, Bristol, Connecticut.

Mr. Martin graduated from Pratt Institute as an industrial-mechanical engineer in 1928 and shortly thereafter joined New Departure as a junior test engineer. Two major projects which he completed were the experimental determination in curved bodies of load-deflection and load-contact area relationships. He was made supervisor of the Physical Test Laboratory in 1932 and held this title for 11 years. In 1943 he was promoted to chief inspector of the Ordnance Plant which was devoted to the production of large bearings for military use.

In 1945 he was attached to the staffs of the chief engineer and the manager of Research and Development. During this time Mr. Martin developed the method of forecasting the life of New Departure self-enclosed, lubricated ball bearings of which he writes in this issue. Six years later he was promoted to his present title.

Three patent applications are now pending as a result of his work in ball bearing design. Mr. Martin is a member of the Society of Automotive Engineers and a former junior member of the American Society of Mechanical Engineers.

WALTER R. MYERS,

co-contributor of "The Engineering Behind Allison's Vertical Take-off Aircraft Exhibit," has devoted his entire career to practical mechanics and to technical instruction, and now serves as co-ordinator of all displays developed in Allison Division for non-Allison use.

Mr. Myers joined Oldsmobile Division in December 1939 as a service representative working with dealers in the Indianapolis zone. Early during World War II he established and conducted at some ten military installations instructor-training schools covering the 20 mm and 50 caliber machine guns produced by Oldsmobile Division. In July 1943 he transferred to Allison Division as a service representative and aircraft engine instructor. He was instrumental in setting up the Dade County Vocational School in Florida, originally intended to teach the maintenance and operation of the V1710 Allison-built engine.

Since the end of the War, he has devoted almost all of his time to Allison displays, specializing in the fabrication of cutaway models of such engines as the 501 turboprop, J35, J33, and the plastic torque converter. This activity is maintained by the Division's Department of Public Relations.

In 1937 he was appointed to the Contest Board of the American Automobile Association and now is the assistant chief observer. As such, he supervises 18 observers who are assigned specific areas of the Indianapolis Speedway during the annual Memorial Day 500-mile race. His interest in car racing began in 1922 when he became associated with Harry Miller's racing car design activities in Los Angeles, and he participated in the building of a 10:1 compression ratio racing engine. Later, he served as chief mechanic for three renowned race drivers and in 1934 he rode in the Indianapolis classic with Mauri Rose, placing second.

'Personal Lessons' Reprints Made Available

Several educators have suggested that reprints be made available to engineering juniors and seniors of "Some Personal Lessons from Five Decades in Engineering," by Arthur J. Altz, Chevrolet Motor Division. This parting message from a widely-known Chevrolet engineer appeared in the January-February 1955 issue.

Chevrolet is reprinting the work in booklet form with a foreword by Chief Engineer Edward N. Cole, and will supply classroom quantities gratis to members of engineering faculties on request to:

Engineering Department
GM Engineering Journal Reprint
Chevrolet—Central Office
General Motors Building
Detroit 2, Michigan

STRAIGHT UP POWER

These sequence photographs depict the Convair XFY-1 *vertical take-off* or *VTO* fighter making a free vertical take-off. A typical landing track is shown by the black arrow.

This versatile aircraft demanded an unconventional engine and Allison engineers succeeded in modifying for its use their T40 turbo-prop engine design. They rearranged the T40's oil pumps, fuel lines, and breathers to enable both horizontal and vertical operation. They also redesigned the reduction gear to give high propeller revolutions per minute and increased thrust—for during landings and take-offs the full load is on the propellers.

This Navy interceptor-fighter rests on the ground in a vertical position and, from this attitude, takes off straight upward, its twin-power-sectioned engine producing 5,850 hp. When the pilot brings the aircraft into horizontal flight, he may cruise at about 250 mph while keeping one of the power sections inoperative and conserving fuel. In an interception, he may use both sections and attain speeds of more than 500 mph. In landing, the pilot brings the VTO's nose straight upward over the landing spot—perhaps the fantail of a freighter. The entire load is then suspended on the propellers and the aircraft eased down in full control of the pilot.

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